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SUPERHEATER EVALUATION STUDIES FOR DD931/DD945 CLASS
BABCOCK & WILCOX BOILERS

NBTL PROJECT B-494
May 1962
by

W. A. FRITZ, JR.
T. P. TURSI, JR.

NAVAL BOILER AND TURBINE LABORATORY
PHILADELPHIA NAVAL SHIPYARD
PHILADELPHIA 12, PENNA.

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TABLE OF CONTENTS

LIST OF PLATES

LIST OF PLATES (Cont'd)

ABSTRACT

Three ships of the DD931 Class experienced tube failures in the superheater third pass. All failures occurred in the same tube row and all boilers inspected revealed similar patterns of fireside corrosion, wall thinning and overheating. Tubes of the USS BARRY (DD933) were inspected and found to have experienced wall thinning up to 54% in certain areas, although no failures. The Naval Boiler and Turbine Laboratory was assigned the responsibility of planning and directing an investigation aboard the USS BARRY in order to evaluate boiler conditions and determine the cause of wall thinning and tube failures. Metal temperatures as high as 1390°F were observed. Various superheater modifications including gas baffling and superheater tube removal were made; appreciable reductions in metal temperatures were observed. Calculations based on the investigation data determined the optimum class modification required to reduce tube metal temperatures.

ADMINISTRATIVE INFORMATION

This project was authorized by BUSHIPS ltr DD931 C1/9510; DD945 C1/9510; Ser 651A-947 of 29 June 1961. Approval for the superheater investigation to be conducted aboard the USS BARRY (DD933) was given by the Commander, Destroyer Force, United States Atlantic Fleet by COMDESLANT dispatch 0319462 of July 1961. Boston Naval Shipyard Request for Performance of Work WR2-0202 of 7 July 1961 provided funds to the Naval Boiler and Turbine Laboratory for the instrumentation of one boiler on the USS BARRY and consultant services for conducting the evaluation. BUSHIPS ltr DD933; Ser 651A-1007 of 27 July 1961 directed that a representative from the Naval Boiler and Turbine Laboratory head the personnel conducting these evaluations.

BACKGROUND

Superheater tube failures by bursting have occurred in superheaters of DD931 Class Babcock & Wilcox boilers. Table 1 gives pertinent facts on failures.

Table 1

DD931 Class Superheater Failures

Ship	Boiler	SH* Tube	Steaming Hours @ Failure
USS FORREST SHERMAN (DD931)	1A	19B	11,892
	1B	19A	11,819
	2B	19B	12,200
USS JOHN PAUL JONES (DD932)	1B	19B	—
USS MANLEY (DD940)	—	19A	—

*NOTE: Tubes numbered 1 through 45 bottom to top, and A through H from furnace side to generating bank side of superheater.

All superheater tube failures had the following similarities:

a. Location of all failures was in tubes of the 19th row from the bottom on the furnace side leg. This 19th row is the top tube row of the lower furnace side header section and has a 2-1/2" space between it and the bottom tube row (20) of the upper header section. The 19th row is in the third pass; the 20th row in the second pass.

b. All tube failures occurred on the outer loop or in the second loop in (the A or B leg).

c. All ruptures occurred on the tube side facing the furnace.

d. All ruptures occurred approximately 30" from the superheater header.

e. All ruptures were thick lipped but varied in size from slits with little bulging to rather large ruptures (4" long x 1-3/4" across the opening) with much bulging.

f. Tube walls in the area of the ruptures had thinned from the gas side on that portion of the tubes facing the furnace. This was especially so in the outer loop tubes, and thinned tubes included tubes from at least the 8th tube from the bottom to the 19th tube from the bottom.

g. All failed tubes were 18 Cr - 8 Ni alloy with nominal wall thickness of 0.156". All tubes in the 3rd and 4th pass are of this material.

During examination of boilers 2A and 2B on FORREST SHERMAN on 5 May 1961, it was noted that there was quite a difference in appearance between the superheater tubes of the top two passes and those of the bottom two. It was noted that the bottom two passes showed signs of corrosion and overheating toward the rear that were not nearly as evident toward the front, and that these signs were non-existent in the upper two passes.

Observations similar to the above were repeated on boiler 1B of JOHN PAUL JONES on 16 May 1961 and were verified by special inspection of FORREST SHERMAN on 31 May 1961 when it was also determined that the 19th, 18th, 17th, 16th and 15th tubes from the bottom showed very definite signs of corrosion as compared to the tubes below them.

Inspection of the USS BARRY (DD933) superheaters from furnace and cavity in early July 1961 showed a similar pattern from the firesides,

but not nearly as accentuated as on FORREST SHERMAN and JOHN PAUL JONES. The difference was undoubtedly due to the fact that BARRY boilers had fewer steaming hours than the boilers of the other two ships.

It was fairly well established that failure of the superheater tubes could be attributed to wall thinning caused by fuel - ash corrosion and high tube metal temperatures. Materials Laboratory, Boston Naval Shipyard (refer to Report No. 1534 of 29 June 1961) estimated that a fractured tube from the FORREST SHERMAN had reached a temperature in the vicinity of 1300°F during boiler operation. This was verified by separate Boiler and Turbine Laboratory data wherein it was determined that the failed tube from JOHN PAUL JONES had operated in the region of 1400°F (refer to Plate 1). Materials Laboratory, Boston Naval Shipyard also determined that superheater tubes from the BARRY experienced up to 54% wall thinning in the A row and up to 48% in the B row, with maximum thinning occurring at tube 19A. It was concluded that this thinning was due to external corrosive attack by fuel oil ash.

It is known that high tube metal temperatures, especially above 1250°F are a prime factor to be considered as concerns the amount and extent of corrosion from residual fuel oil ash. The amount of erosion-corrosion which takes place in a particular boiler will also depend upon gas temperatures and gas velocities entering the various sections of the superheater and the amount and condition of the ash carried along with the gases of combustion. It has been considered that perhaps both gas flow and steam flow maldistribution have increased the corrosion

rate on the superheaters in boilers of the FORREST SHERMAN type. To somewhat improve gas flow distribution and to provide some initial improvement in the superheaters of the DD931 and DD945 Class, a gas baffle for installation in the space between the 2nd and 3rd passes on the superheater furnace side was recommended by NBTL and was authorized by Bureau of Ships dispatch 022038Z of 1 June 1961.

The superheaters of the DD931 Class Babcock & Wilcox boilers have four passes containing a total of 180 U-type tubes. Each tube row consists of four separate U-loops so arranged that the space between legs of the innermost loop provides sufficient room for a person to enter the superheater cavity. Both inlet and outlet headers are on the generating bank side of the superheater with the inlet header being at the top. Two rows of staggered two-inch screen tubes are located between the furnace and the superheater bank. Superheater tubes of the first two passes are 1-1/4" OD by 0.156" thick and are to Military Specification MIL-T-16286B, Class e which is 2-1/4% Cr. 1% Mo. Tubes of the last two passes are 1-1/4" OD by 0.156" thick and are to the same specification, but are class C which is 18% Cr, 8% Ni, austenitic. The working pressure of the superheater is 1250 psig and the steam temperature at the superheater outlet is a minimum of 92[illegible]°F at cruising and full power not to exceed 970°F at any rate.

Bureau of Ships ltr DD931 C1/9510, DD945 C1/9510; Ser 651A-947 of 29 June 1961 and Boston Naval Shipyard Request for Performance of Work WR2-0202 of 7 July 1961 requested that Babcock & Wilcox DD931/DD945 Class boilers be evaluated to determine the conditions in the superheaters

which led to tube thinning and failure. These evaluations were conducted on Boiler 2B of the USS BARRY (DD933) in accordance with the Agenda, Appendix I. Some portions of the Agenda such as excess air and high speed lighting off runs were not conducted since high super heater tube temperatures were observed and evaluated during normal boiler operations.

Knowledge gained from this evaluation resulted in a class modification (Condition D - see "Purpose of Test") which was installed on all boilers of the USS JOHN PAUL JONES by direction of Bureau of Ships dispatch 252026Z of October 1961.

REPORT OF INVESTIGATION

PURPOSE OF TESTS

The primary consideration of this evaluation was to make an analysis of a superheater in a DD931 Class Babcock & Wilcox steaming boiler to determine (1) conditions under which tube corrosion is taking place, (2) what measures can be taken to extent superheater life, and (3) methods that can be used to predict superheater tube life. These objectives were obtained by instrumenting one superheater to primarily determine the following: (1) tube metal temperatures in the second, third, and fourth pass superheater tubes, (2) steam temperatures at various locations in the superheater steam passes; (3) combustion gas temperatures in the superheater cavity; and (4) supplementary information to assist in making a complete analysis of the problem. Pertinent plan drawings are shown in Plate 2, sheet 1 through 4.

This evaluation was conducted on Boiler 2B of the USS BARRY (DD933) with the following boiler conditions (refer to Plate 3) existing for

each phase of testing:

a. Condition A - Original configuration of USS BARRY Boiler 2B. This configuration is the same as the final configuration of the Laboratory's DD931 Class test boiler as reported under NBTL Report B-168.

b. Condition B - Same as Condition A except that a refractory brick baffle was added in the lane between the second and third superheater passes (Tube 19 and 20) extending over the entire furnace depth.

c. Condition C - Same as Condition A except that superheater tube row 19 (plan pieces 805, 806, 807 and 808) and third pass inner loop tubes 14 through 18 (plan piece 808) were removed. A refractory brick baffle was placed between superheater tube rows 18 and 20, which extended over the entire furnace depth.

d. Condition D - Class modification arrived at by evaluation of data obtained during conditions A, B, and C testing aboard the USS BARRY. This boiler condition is the same as condition A except that tube row 19 (plan pieces 805, 806, 807 and 808) and the entire third pass inner loop tubes (plan piece 808) are removed. In order to maintain the support structure of the superheater, cast slugs are installed in the spaces left by the removed tubes as shown in Plate 4.

METHOD OF TEST

General

These evaluations were conducted on Boiler 2B of the USS BARRY (DD933) in conjunction with Post Repair Trials out of Boston Naval Shipyard during September and October 1961, in accordance with the

Agenda, Appendix I. Installation and initial checkout of all instrumentation was completed on 28 September 1961. The complete shipboard testing program ran from 29 September to 9 October 1961; of this time, four days were required to complete the evaluation of the shipboard boiler Conditions A, B, and C, while the intermediate working days were consumed in completing boiler modifications to Conditions B and C.

The Laboratory was assigned the responsibility of planning, coordinating, conducting, evaluating and reporting on the test with assistance from the Boston Naval Shipyard and ship's complement.

Instrumentation

The arrangement and details of instrumentation for the superheater evaluation was as shown in Plate 5, and is summarized as follows:

a. Tube Metal Temperatures - A total of eleven thermocouples were installed on the outer skin of the superheater tubes with all hot junctions in the gas path 30" from the centerline of the superheater headers. Starting to count superheater tubes from the bottom, last pass, and labeling tube legs A to H beginning with the furnace side leg, the following tube locations had thermocouples: 1A, 1E, 8A, 8E, 8H, 9A, 13A, 18A, 19A, 19B, and 20A.

b. Steam Temperatures - Thermocouples were installed to indicate steam temperature in the various superheater circuits. These were installed in the superheater tubes adjacent to the superheater headers in the header vestibule. Using the same numbering procedure as in subparagraph A above, these steam temperature thermocouples were located as follows:

(1) Boiler Conditions A and B - Total of 32 thermocouples located at: 1A, 1D, 1E, 1H, 8A, 8D, 8E, 8H, 9A, 9D, 9E, 9H, 13A, 13H, 16A, 18A, 18H, 19A, 19D, 19E, 19H, 20A, 20D, 20E, 20H, 27A, 27H, 31A, 31H, 32A, 32H, and 42A.

(2) Boiler Condition C - Total of 36 thermocouples located at: 1A, 1D, 1E, 1H, 3A, 3H, 5A, 5D, 5E, 5H, 8A, 8D, 8E, 8H, 9A, 9D, 9E, 9H, 13A, 13H, 16A, 18A, 18C, 18F, 18H, 20A, 20D, 20E, 20H, 27A, 27H, 31A, 31H, 32A, 32H, and 42A.

c. Two multi-shielded high velocity thermocouple probes were installed in the superheater cavity to obtain gas temperatures. One was located in the gas path between the third and fourth passes and the other between the second and third passes. These probes could be traversed through the furnace depth.

d. Five thermocouples were installed in the gas path before, and five after the economizer.

e. A pencil type thermocouple was installed at the superheater outlet to measure final steam temperature.

f. Pencil type thermocouples were installed at both forced draft blower discharges to measure combustion air temperature to the boiler.

g. Economizer water inlet and outlet temperatures were measured by peened thermocouples.

h. CO_2, CO, and O_2 percentages in the stack gas were measured using a cone primary element and an Orsat apparatus for analysis and readout.

i. Ship's instrumentation was used to obtain fuel oil supply

pressure and the following steam pressures: steam drum, superheater outlet, desuperheater inlet, and desuperheater outlet during Conditions A and B testing. For condition C testing, two 16" Laboratory test gages were installed for measurement of drum and superheater outlet pressures in order to permit more accurate evaluation of pressure drop.

j. Fuel oil rate to the test boiler was obtained from the ship's fuel oil meter and verified by sprayer plate capacity curves using fuel pressure obtained from ship's fuel supply pressure gage.

k. Air pressure at the windbox was obtained using ship's manometer.

l. Fuel oil samples were obtained during test and later analyzed. Samples were taken twice during each day's testing from a line tapped directly off the burner fuel supply manifold.

<u>Procedure</u>

Boiler Condition A - Shipboard evaluation of the USS BARRY Boiler 2B under this condition was conducted on 29 and 30 September 1961. Data was observed during boiler light-off and shut-down, ship's maneuvering into and out of port, steady ship's speeds at boiler rates of 10, 15, 20, and 25 knots and boiler full power. Boiler data was also observed during 10 to 25 knot, and 25 to 10 knot maneuvers, as well as during soot blowing of tubes at the 25 knot boiler condition. The burner combinations and sprayer plates used during all operations were essentially in agreement with the recommendations of NBTL Report B-168, except when burner changes were made at the request of the test engineer in order to observe the effects of varying burner combinations on superheater tube metal and final steam temperatures.

Boiler Condition B - The shipboard evaluation of the USS BARRY Boiler 2B under this condition was conducted on 3 October 1961. Boiler data was observed for essentially the same operational conditions as for Condition A described above.

Boiler Condition C - Test instrumentation for this Condition C was slightly modified as noted in the instrumentation section above. Shipboard evaluation of the USS BARRY Boiler 2B under this condition was conducted on 9 October 1961. Boiler data was observed for essentially the same operational conditions as for Conditions A and B described above.

RESULTS OF TESTS

Superheater tube metal temperatures were observed to be extremely high (refer to Plate 6) during Condition A steady state runs. Tube 19A was 1200°F at the 15 knots condition, and reached a maximum of 1390°F at the 25 knots condition. Condition B resulted in an appreciable reduction in tube 19A metal temperatures, yielding 1100°F at 15 knots and 1300°F at 25 knots. This condition, however, had negligible effect on tube 19A at full power where a maximum of 1350°F occurred. Tubes 13A, 18A and 19B remained from 50 to 75°F below tube 19A during Condition A, and reduced proportionally during Condition B.

During Condition C operation, tubes 13A and 18A dropped to 1160°F at 25 knots, but reached 1265°F at full power. Plate 7 gives comparison of tube 19A metal temperatures for A and B Conditions, and Plate 8 compares tube 18A metal temperatures for all Conditions A, B, and C.

Final steam temperatures for shipboard Conditions A, B, and C are presented in Plate 9. The Condition A curve steadily rises from low

rate to full power with no apparent peak value at any rate. For Condition B the final steam temperature dropped slightly at rates below cruising, but remained essentially unchanged at rates above cruising. Condition C caused final steam temperature to drop approximately 25°F to 40°F at all rates.

CLASS MODIFICATION

Data from this superheater evaluation was independently evaluated by the Bureau of Ships, Babcock & Wilcox Company, and the Naval Boiler and Turbine Laboratory. A conference was held at the Bureau of Ships on 20 October 1961 to discuss the results of these tests and to evaluate an optimum class modification. The class superheater configuration resulting from this meeting is as previously described under boiler Condition D and involves the removal of 14 tubes from the superheater third pass and the addition of a refractory gas baffle in the lane between the second and third superheater passes. These alterations are schematically presented in Plate 3. Cast slugs are installed in place of the removed inner loop tubes in order to maintain the superheater support structure as shown in Plate 4.

CALCULATIONS

Calculations were made (refer to Appendix II for procedure) based on Conditions A, B, and C operation in order to evaluate heat transfer coefficients, and to permit prediction of the effects of further superheater modifications on final steam temperature and superheater tube metal temperatures. Results indicate that removal of additional tubes from the third pass (above that number removed in Condition C)

will result in acceptable tube metal temperatures, with neither excessive reduction of final steam temperature nor excessive increase in steam pressure drop through the superheater. This modification is to be accomplished by boiler Condition D previously described.

Calculations indicate that boiler Condition D will result in an appreciable reduction of metal temperature in the remaining upper tubes of the third pass. Tube 18A is indicative of this condition in that it experienced temperatures above 1300°F during Condition A, and a maximum of 1200°F is calculated for it during Condition D. The lower tubes of the third pass were improved greatly by Condition C, but would be relatively unaffected by Condition D. These calculations indicate that maximum metal temperatures within the third pass will be in the vicinity of 1175 to 1250°F at 75% to 100% of boiler full power, with lesser temperatures at other boiler rates. Metal temperatures obtained for Conditions A, B, and C as compared with calculated values for Condition D for selected tubes in the superheater third pass are presented in Plate 10.

Calculations further indicate that the mean gas flow through the third pass for Condition D will be 85% greater than Condition A and 32% greater than Condition C at the full power boiler rate.

The estimated final steam temperature for boiler Condition D is presented in Plate 9, and was obtained by linear extrapolation of the A, B, and C Condition curves. This temperature is 925°F at full power and 850°F at cruising which falls below the originally specified minimum of 925°F at cruising.

Tabulated data for Conditions A, B, C and D are presented in Plate 11.

SUMMARY AND DISCUSSION

The superheater evaluations conducted on Boiler 2B of the USS BARRY (DD933) yielded information on superheater tube metal and final steam temperatures for three boiler conditions: A - original shipboard configuration, B - gas baffle added in lane between second and third superheater passes, and C - nine tubes removed from superheater third pass and gas baffle added in lane between second and third superheater passes.

Condition A resulted in tube metal temperatures as high as 1390°F in tube 19A and 1340°F in tube 18A. Condition B reduced these temperatures appreciably at all boiler rates except full power, where the temperature reduction was negligible. Condition C further reduced metal temperatures for the intermediate and full power boiler rates and resulted in a maximum of 1265°F for tube 18A at full power. Tube 19A was among those removed.

Superheater outlet temperatures for Condition C were reduced approximately 35°F over the entire range of boiler rates resulting in temperatures of 890°F at cruising and 945°F at full power.

Based on information gained in this evaluation, it was mutually agreed by the Bureau of Ships, Babcock & Wilcox Company, and the Naval Boiler and Turbine Laboratory that a class modification (Condition D) should include the removal of 14 tubes from the superheater third pass and the addition of a gas baffle in the lane between the second and the third superheater passes. This modification required the addition of

cast slugs in place of the removed tubes to maintain the superheater support structure.

Calculations predicting superheater metal temperatures for this class modification indicate that maximum metal temperatures will be in the vicinity of 1175 to 1250°F at boiler rates of 75% to 100% of full power. It also appears that gas flow through the third pass will be 85% greater than Condition A and 32% greater than Condition C at the full power boiler rate. Even with this increased gas flow it is fairly certain that superheater tube wall thinning will be appreciably reduced since the resultant metal temperatures are below the range where serious fuel oil ash corrosion takes place. Fuel oil ash products contributing mostly to corrosion are vanadium pentoxide and sodium sulphate which have melting points at 1274°F and 1625°F respectively. These products have the most corrosive effect in the molten state and therefore at temperatures above their melting points. Plate 12 shows there is a definite relation between maximum tube metal temperature and amount of wall thinning experienced by the tubes. Tube 19A which experienced temperatures as high as 1390°F during Condition A operation, reduced 54% in wall thickness, whereas tube 9A which experienced 1260°F lost only 31% of wall thickness.

Calculations for Condition D indicate that temperatures for third pass tubes will be 1175°F to 1250°F. Wall thinning at worst will be equal to that experienced by tubes 8A and 9A during Condition A operation, or about 30% in 10,000 to 11,000 hours. FORREST SHERMAN Boiler 2B superheater tube 19B had reduced 66% at time of failure; tube 19A also reduced 66% but had not failed. This indicates that

Condition D can operate for at least 20,000 hours before tube walls are reduced to the range required for failure.

RECOMMENDATIONS

It is recommended that superheaters of the DD931/DD945 Class ships be modified to the boiler Condition D previously described.

Work on this project indicates two areas which should be considered for further study: One is to investigate possible superheater configurations and locations which will result in lower tube metal temperatures. The second is a quantative evaluation of the effects of gas velocity on the wall thinning of tubes by the dual process of erosion and corrosion in order to allow more accuracy in predicting tube life.

ACKNOWLEDGEMENTS

The cooperation of the ship's Commanding Officer, his officers and men during these evaluations is sincerely appreciated. Special appreciation is given to LT. R. C. Trossbach, Engineering Officer, for his expeditious handling of requests.

The assistance of Mr. Allyn Lee of the Bureau of Ships in planning, coordinating and conducting these superheater evaluations is greatly appreciated.

The services of Mr. H. Teitelman and Mr. A. Sommerville of the Boston Naval Shipyard in rapidly completing boiler modifications is appreciated.

Mr. Leonard Cohen, Laboratory Technical Specialist, gave valuable assistance in a consulting capacity.

NBTL PROJECT B-494

DD 931 SUPERHEATER STUDIES

USS JOHN PAUL JONES (DD 932) BOILER 1B

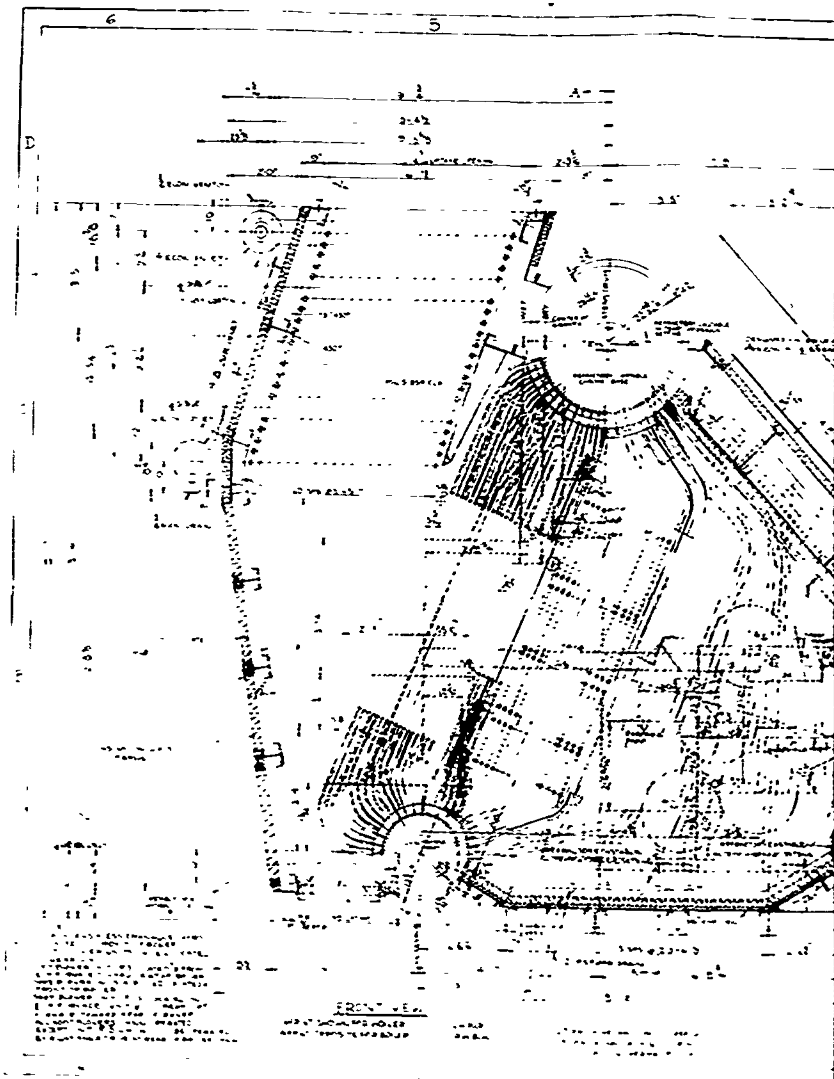
EXAMINATION OF FAILED SUPERHEATER TUBE

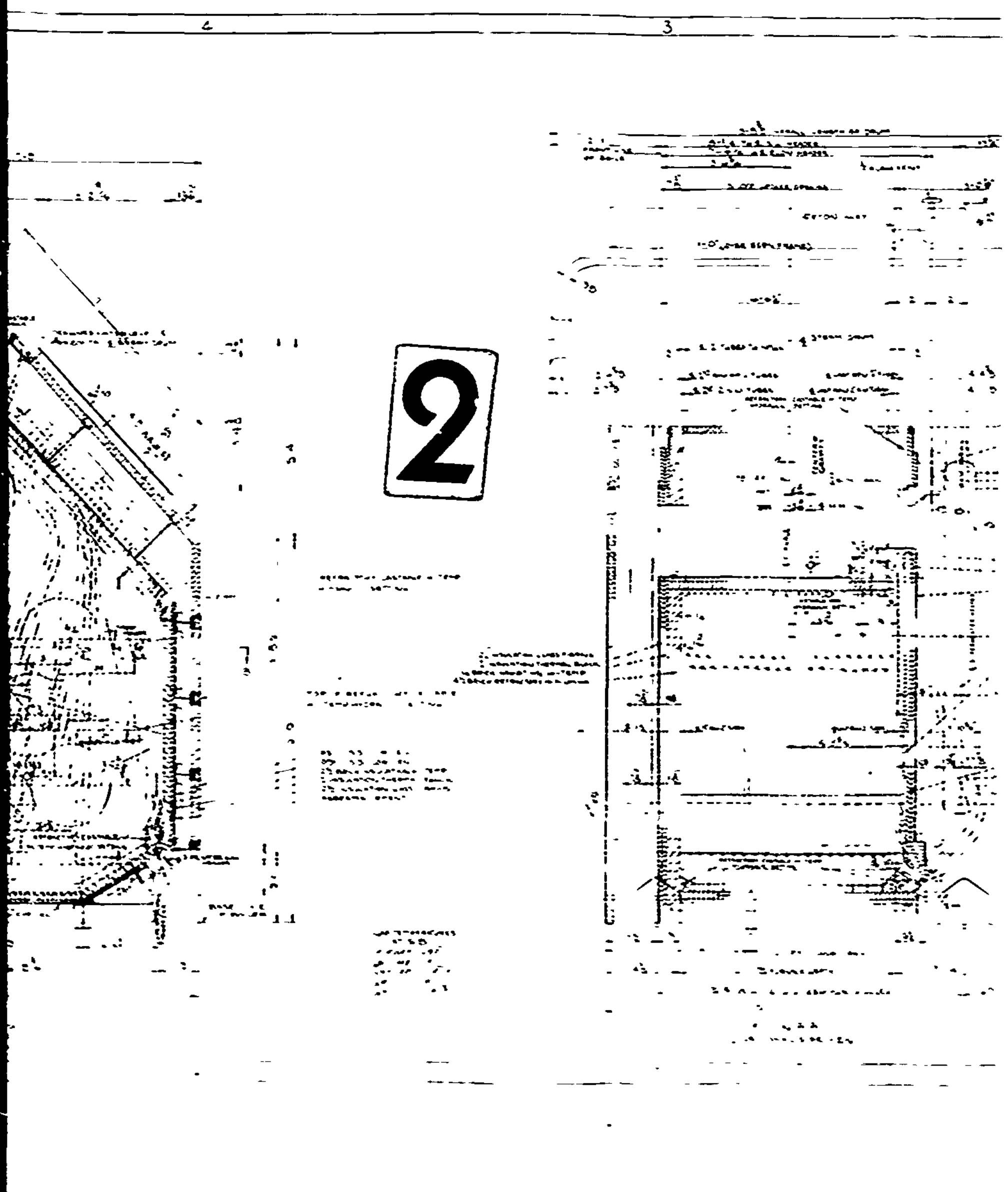
	TUBE 19 A OUTER			TUBE 19 B INNER		
DISTANCE FROM ℄ OF S.H. HEADER	TUBE WALL TEMP	TUBE WALL THICK	TUBE HARDNESS	TUBE WALL TEMP	TUBE WALL THICK	TUBE HARDNESS
IN.	°F	IN	ROCK B	°F	IN	ROCK B
14	1425	.118	82	1350	.109	82
16	—	.103	84	1375	—	94
17.5	—	—	—	--	.082	94
18	—	.105	81	1400	.072	74.
20	—	.119	86	—	.099	85
23	1400	.123	84.5	1375	.115	93
26	—	—	—	—	.121	88
32	1375	.135	88	1375	.119	88
38	—	—	—	—	.130	96
41	1375	.147	88	1350	.138	91
49	1350	.159	92	1350	.153	95
55	—	—	—	—	.160	93
58	1300	.160	92	—	—	—
61	—	—	—	1350	.157	92
68	1325	.159	93	—	—	—
70	—	—	—	1325	.155	92

Note: Failed Section Boxed

PLATE 1

1

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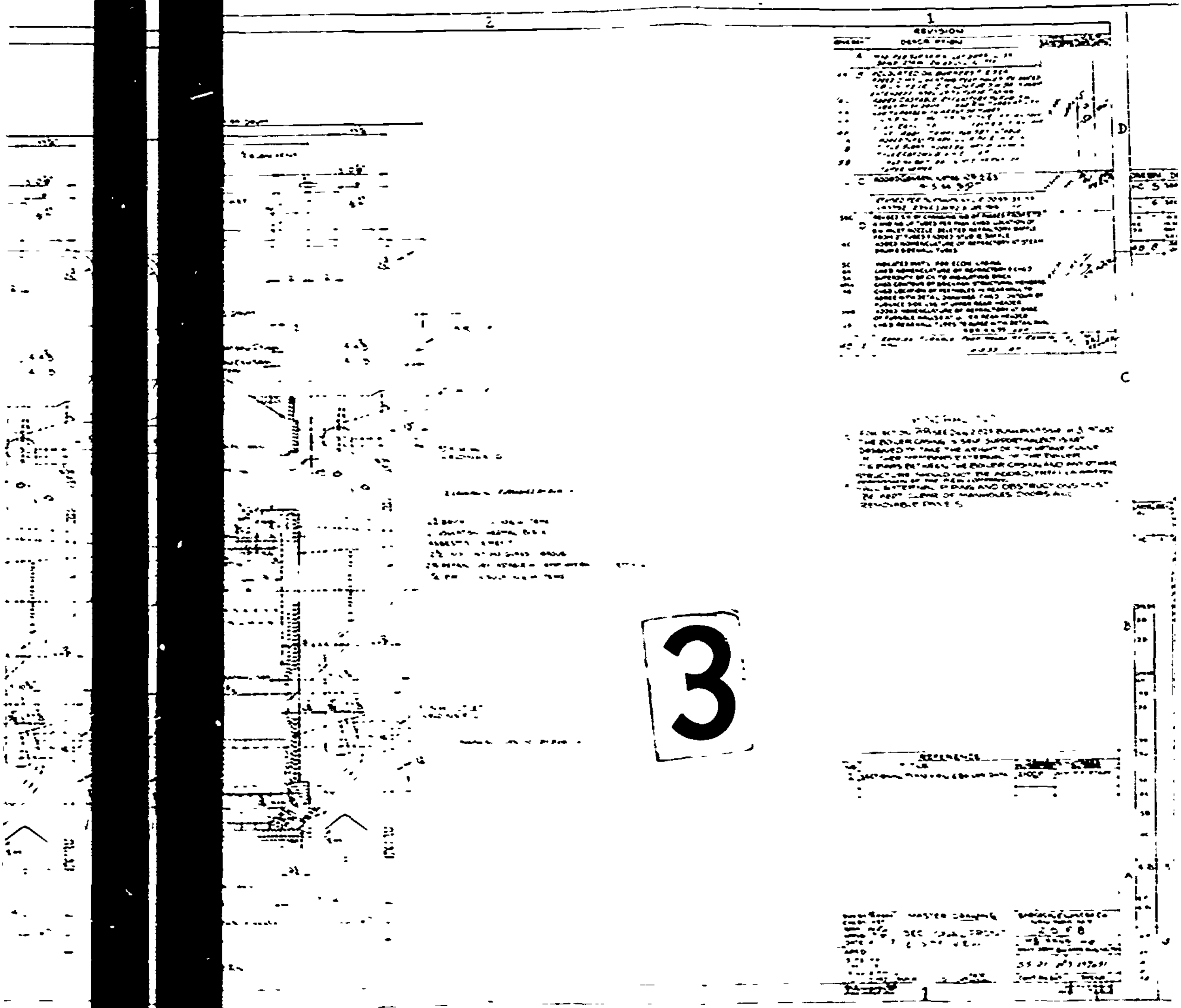


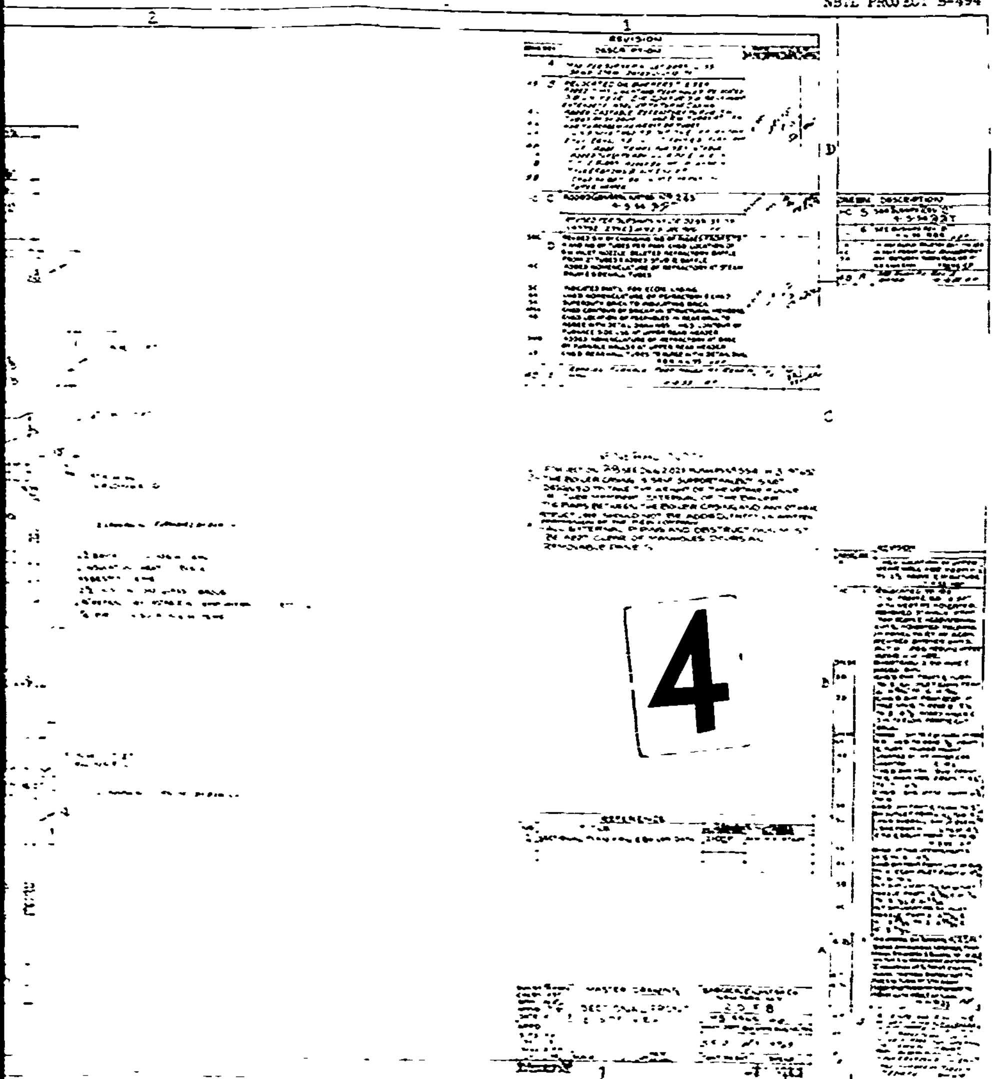
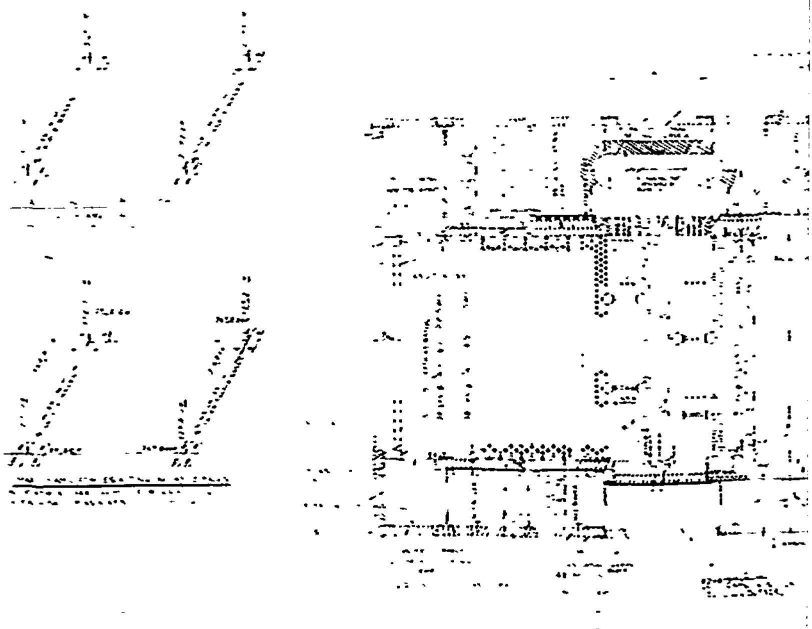


PLATE 2
SHEET 1 of 4

1



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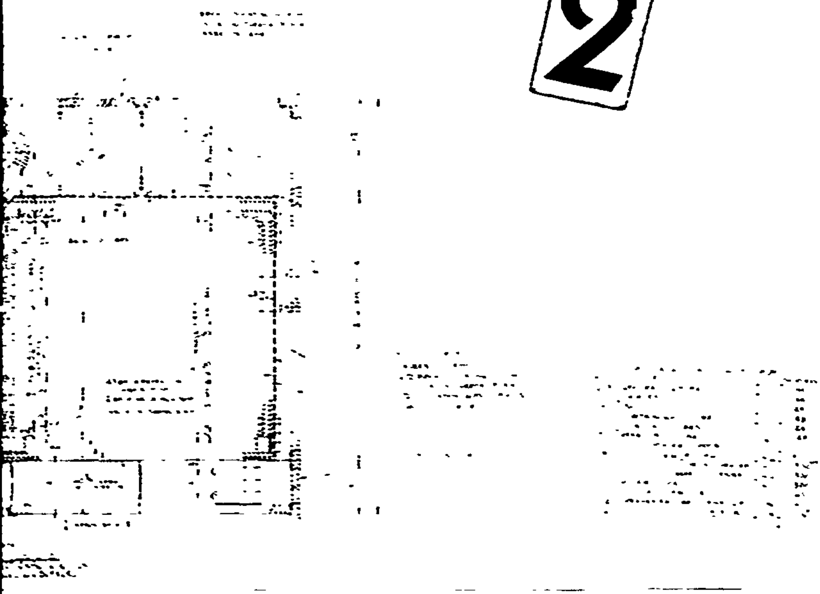

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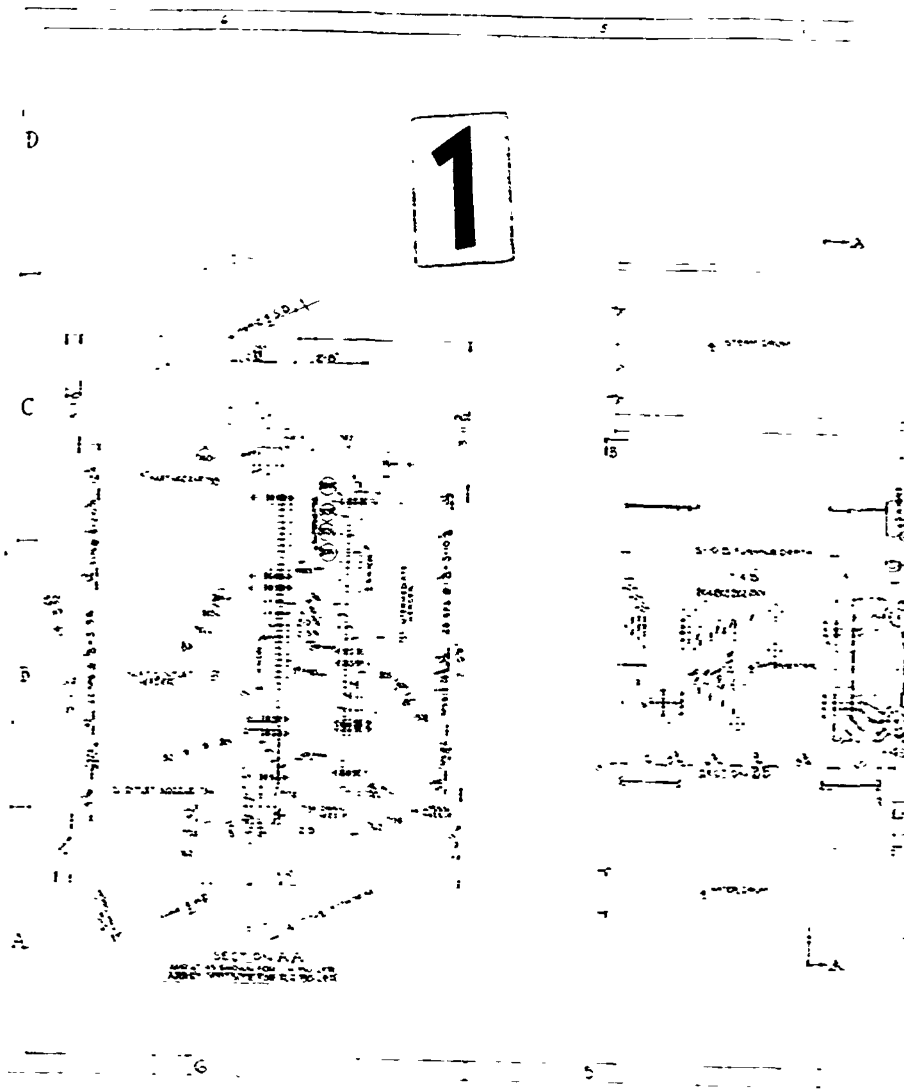
PLATE 2
SHEET 2 of 4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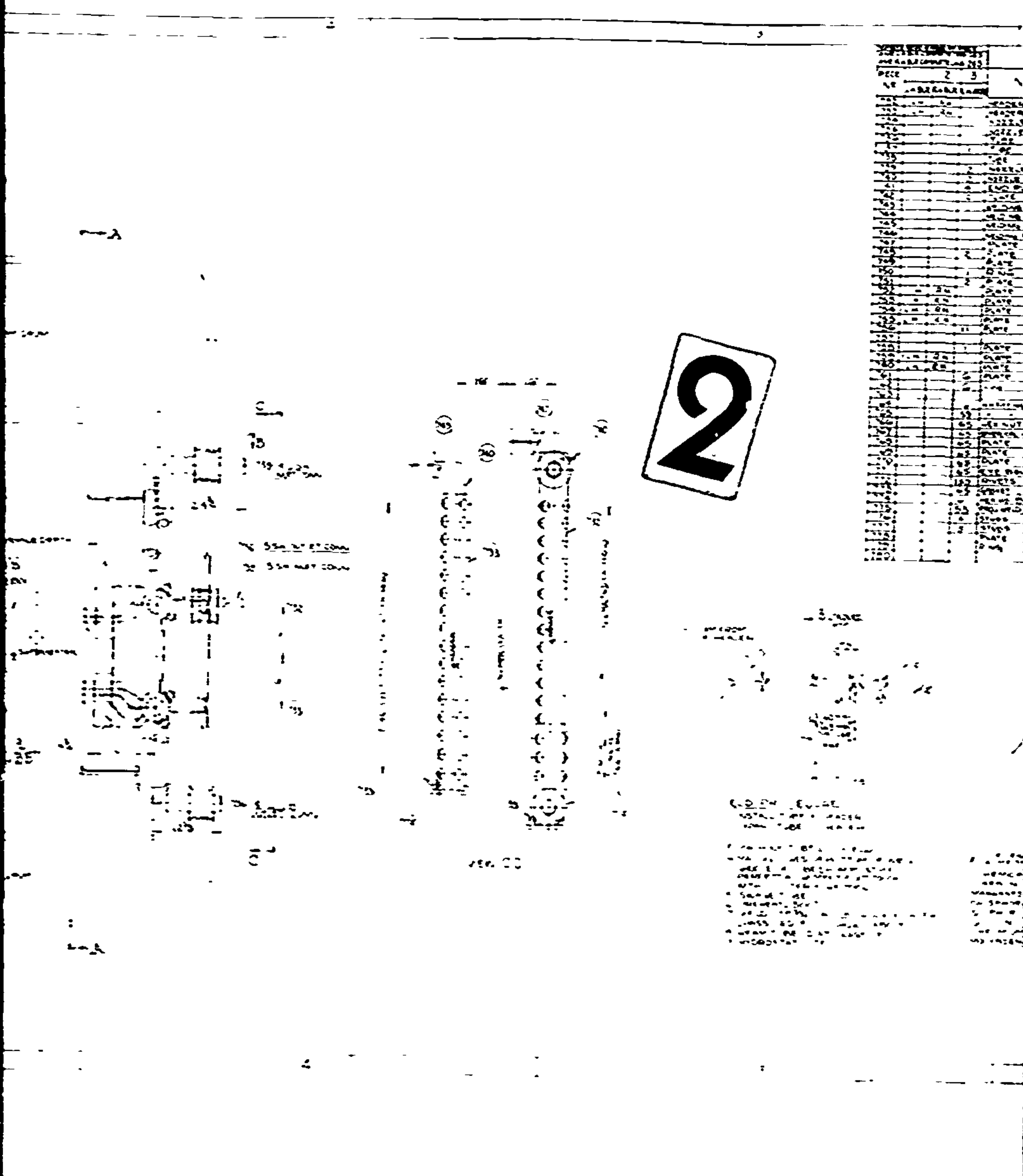
SECTION A-A



NBTL

LIST OF MATERIAL FOR ONE BOILER

	NAME	MATERIAL	MTL SPECS	SIZE	B&W CO	BU SHIPS DWG NO	STD NAVY STOCK NO	REMARKS
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

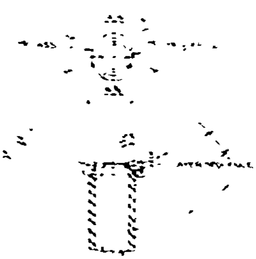
REVISIONS

	DESCRIPTION	
[illegible]	[illegible]	[illegible]

3

GENERAL NOTES

MATERIAL NOTES



ARRANGEMENT OF SUPERHEATER

LIST OF MATERIAL FOR ONE BOILER

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REVISIONS

DESCRIPTION

D

GENERAL NOTES

MATERIAL NOTES

C

B

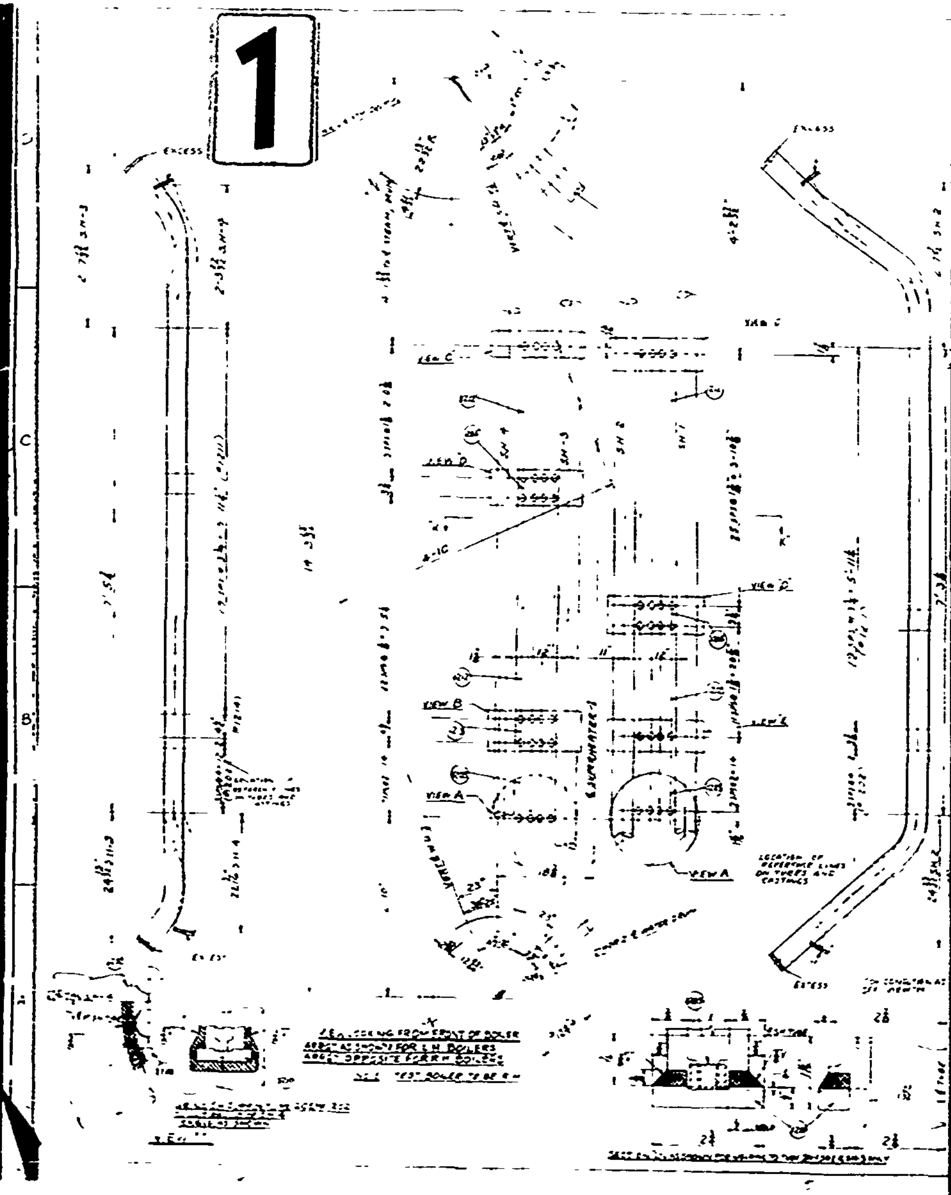
B&W REVISIONS

DESCRIPTION

A

ARRANGEMENT OF
SUPERHEATER

4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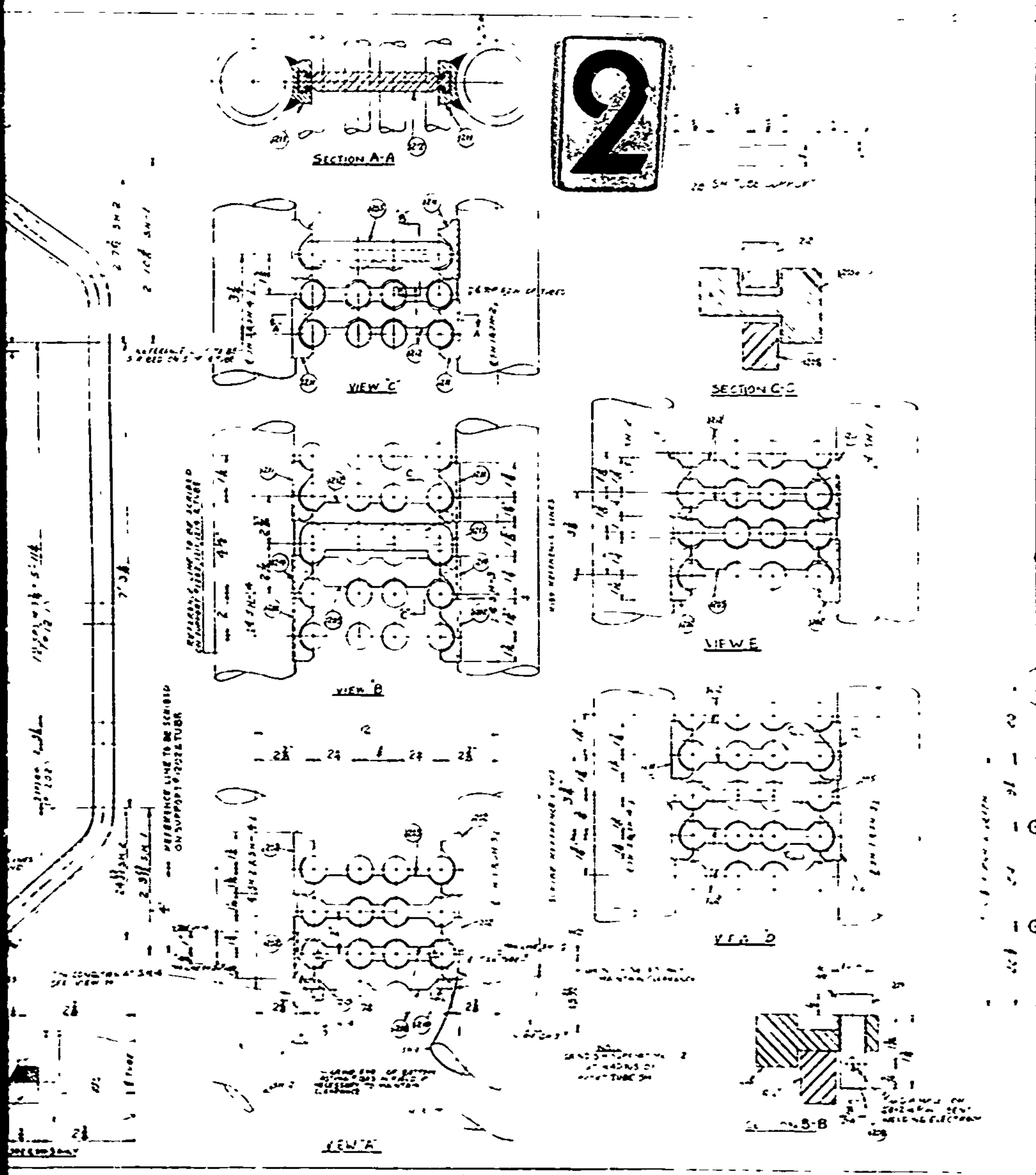
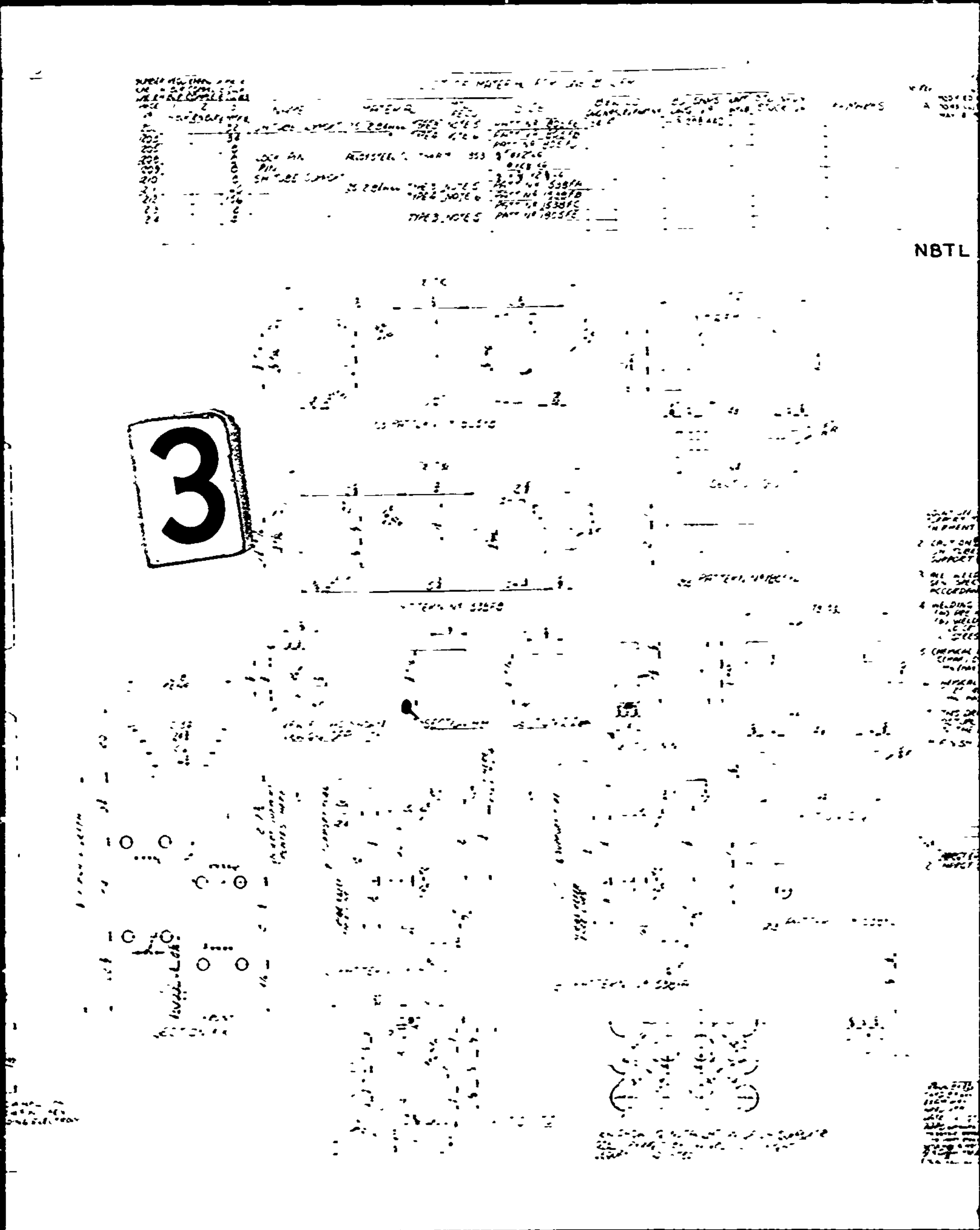
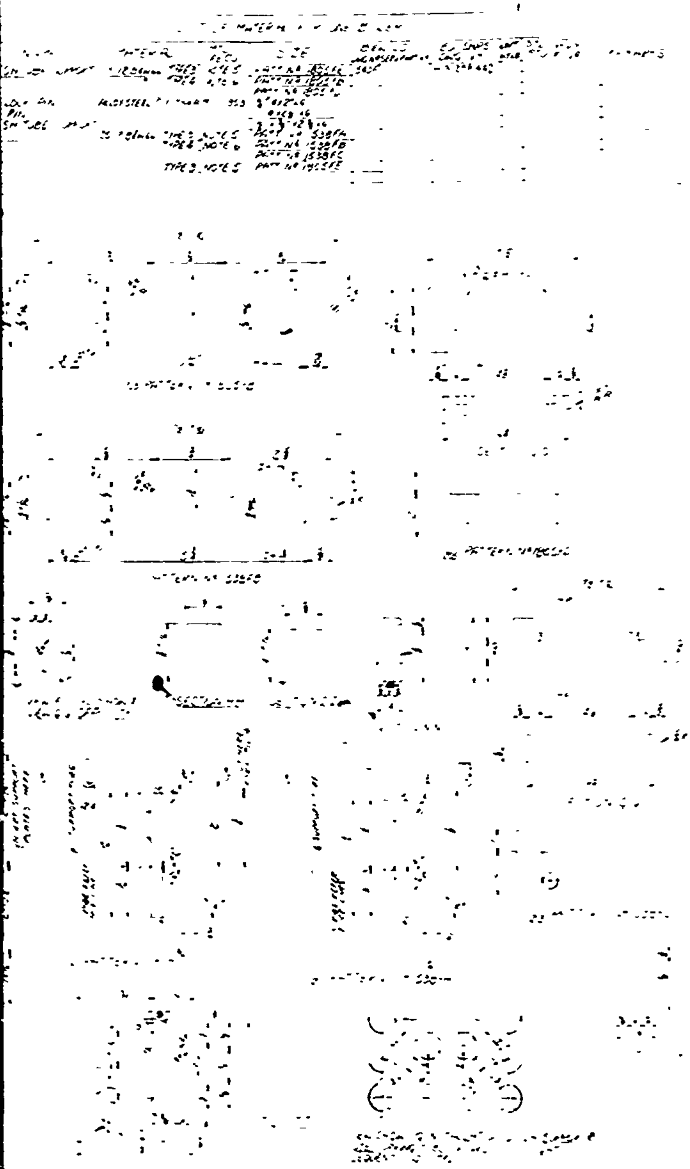
EXCESS
VIEW C
VIEW D
VIEW B
VIEW A



2
SECTION A-A
VIEW "C"
SECTION C-C
VIEW "B"
VIEW E
VIEW "A"


NBTL
3



NBTL PROJECT B-494

4

PLATE 2
SHEET 4 OF 4

NBTL PROJECT B-494

DD 931 SUPERHEATER STUDIES
USS BARRY (DD 933) BOILER 2B

SUPERHEATER MODIFICATIONS

CONDITION A (ORIGINAL SHIPBOARD)

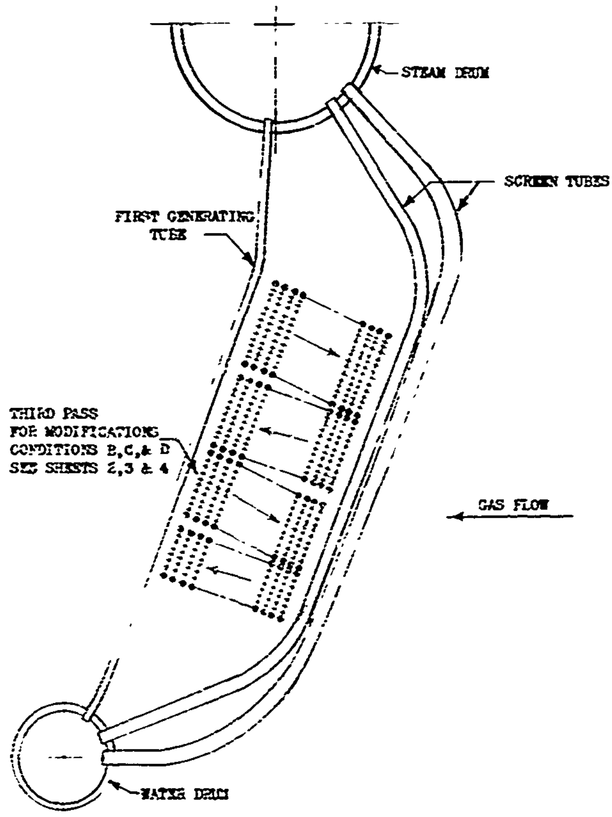
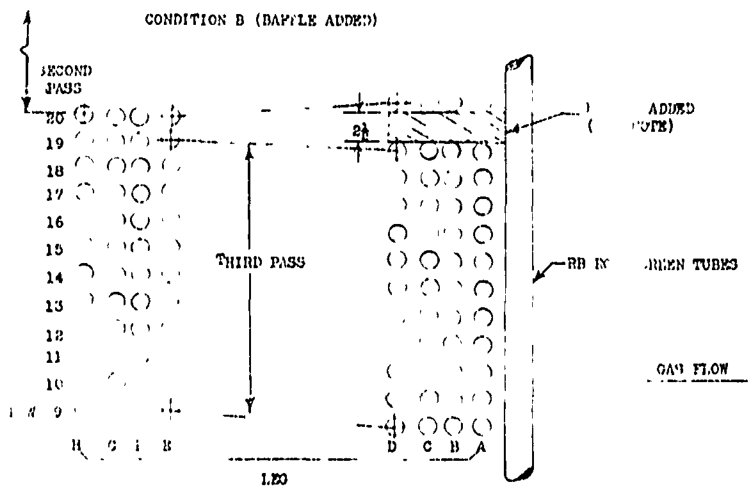


PLATE 3
SHEET 1 OF 4

DD 931 SUPERHEATER STUDIES
USS BARRY (DD 933) BOILER 2B

SUPERHEATER MODIFICATIONS

CONDITION B (BAFFLE ADDED)

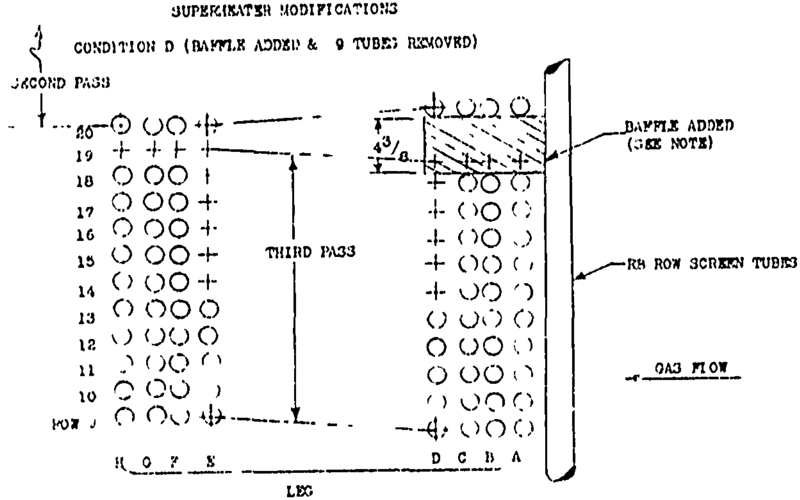


NOTE: BAFFLE ADDED- STANDARD FIRE BRICK 9 x 4½ x 2½
INSTALLED ENTIRE DEPTH OF FURNACE

DD 931 SUPERHEATER STUDIES
USS BARRY (DD 933) BOILER 2B

SUPERHEATER MODIFICATIONS

CONDITION D (BAFFLE ADDED & 9 TUBES REMOVED)

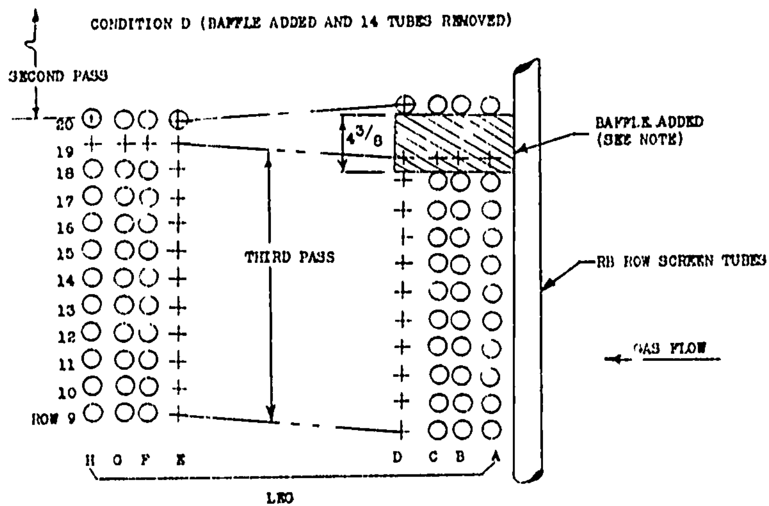


NOTE: BAFFLE ADDED- STANDARD FIRE BRICK 9 x $4\frac{1}{2}$ x $2\frac{1}{2}$ GROUND TO 9 x $4^3/_8$ x $2\frac{1}{2}$, and INSTALLED ENTIRE DEPTH OF FURNACE

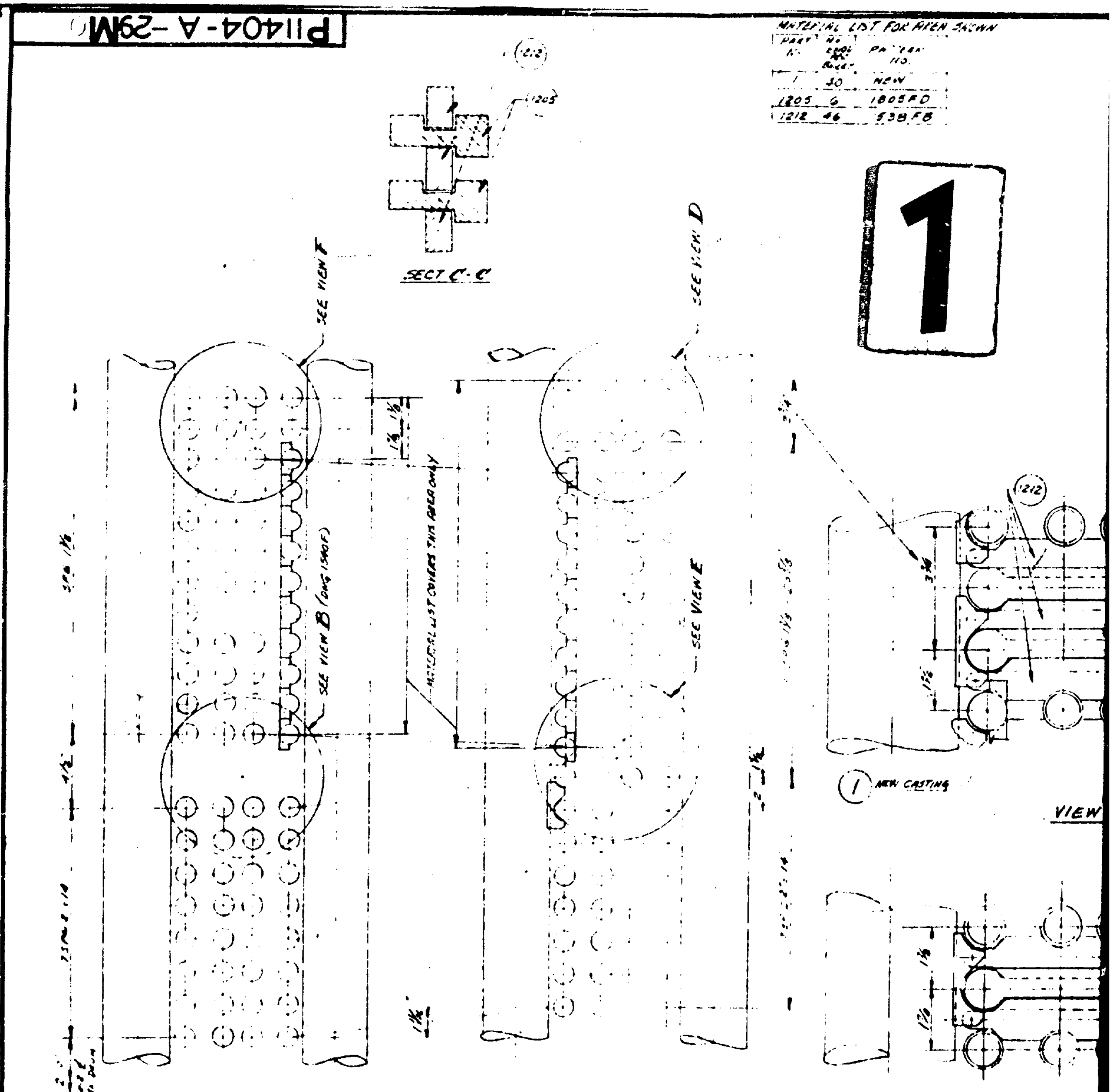
DD 931 SUPERHEATER STUDIES
USS BARRY (DD 933) BOILER 2B

SUPERHEATER MODIFICATIONS

CONDITION D (BAFFLE ADDED AND 14 TUBES REMOVED)



NOTE: BAFFLE ADDED- STANDARD FIRE BRICK 9 x $4\frac{1}{2}$ x $2\frac{1}{2}$
GROUND TO 9 x $4^3/_8$ x $2\frac{1}{2}$ AND INSTALLED
ENTIRE DEPTH OF FURNACE

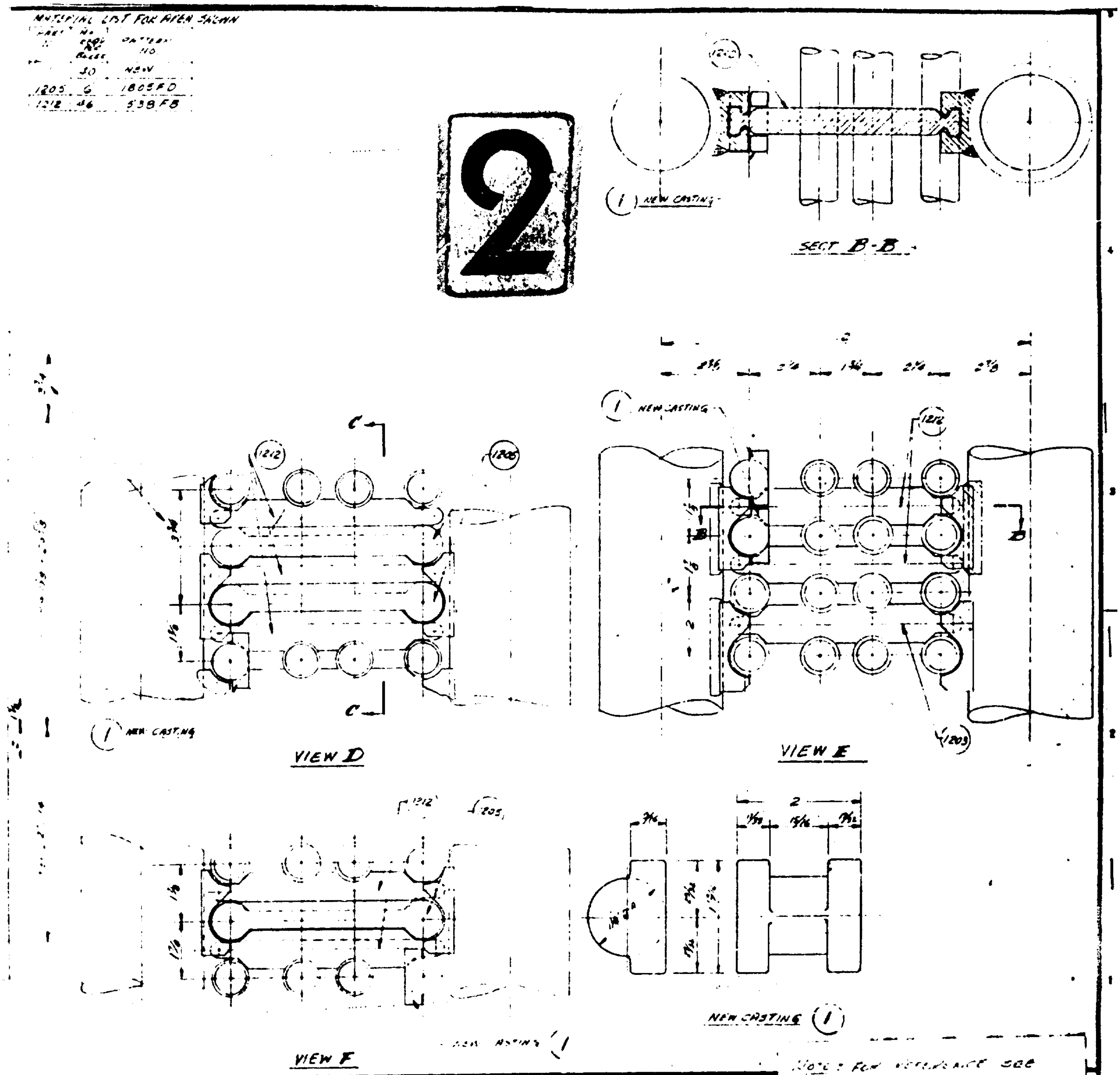


SECTIONAL ELEVATION
(SCALE 3"=1'-0")

THIS DRAWING NOT TO BE USED FOR CONSTRUCTION PURPOSES.

						DESCRIPTION OF REVISION	
0	HRW	HRW	CB	HM			
1							
2							
3							
4							
5							
6							
7							
8							

PROPOSED TO



PROPOSED TO

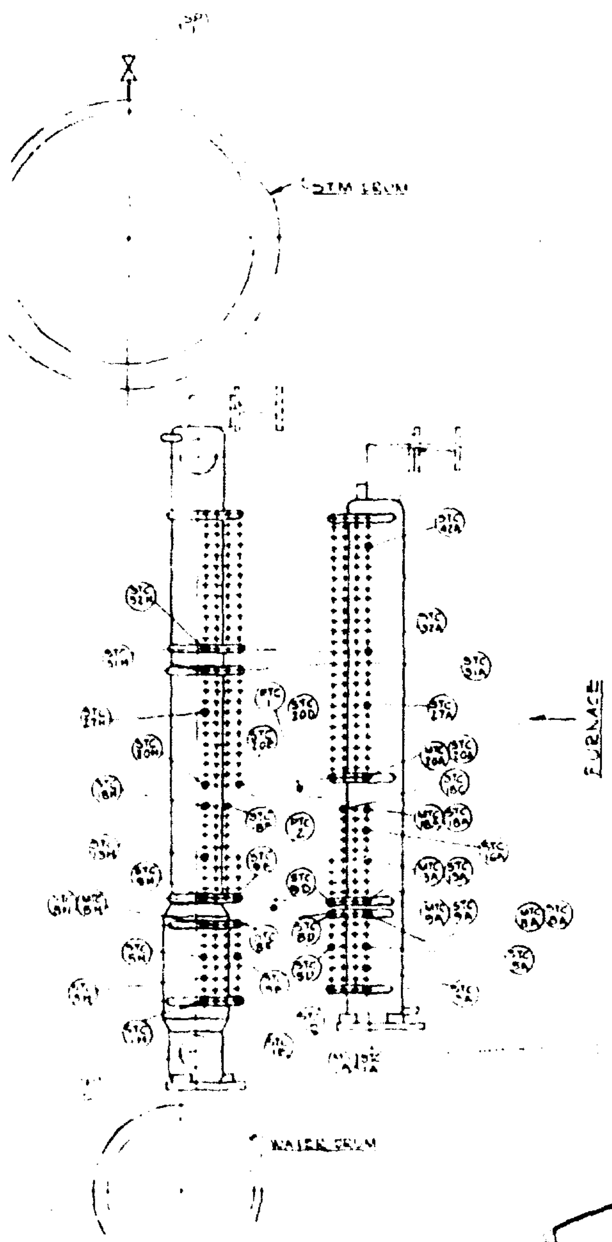
THIS DRAWING IS THE PROPERTY OF
THE
BABCOCK & WILCOX
COMPANY

PROPOSED ALTERATION TO S.H. SUPPORT CASTINGS-3RD PASS

PLATE 4

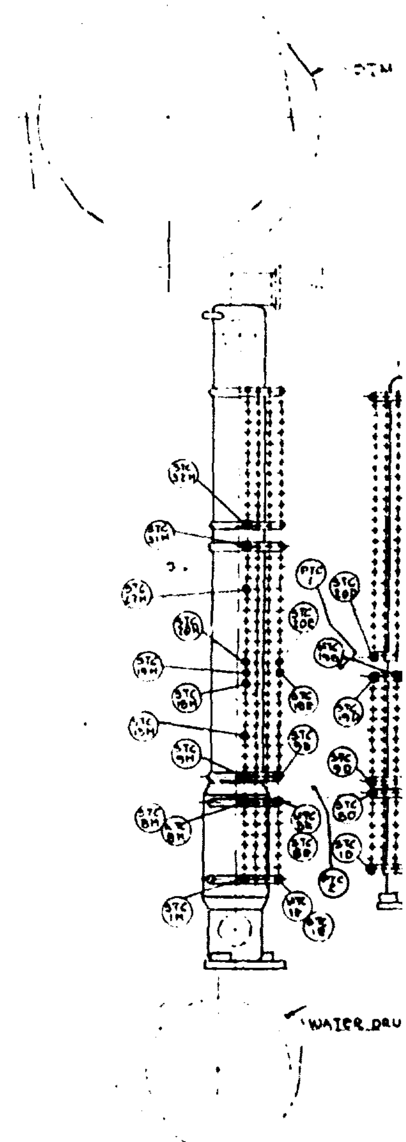
P11404-A -29M0

Best Available Copy

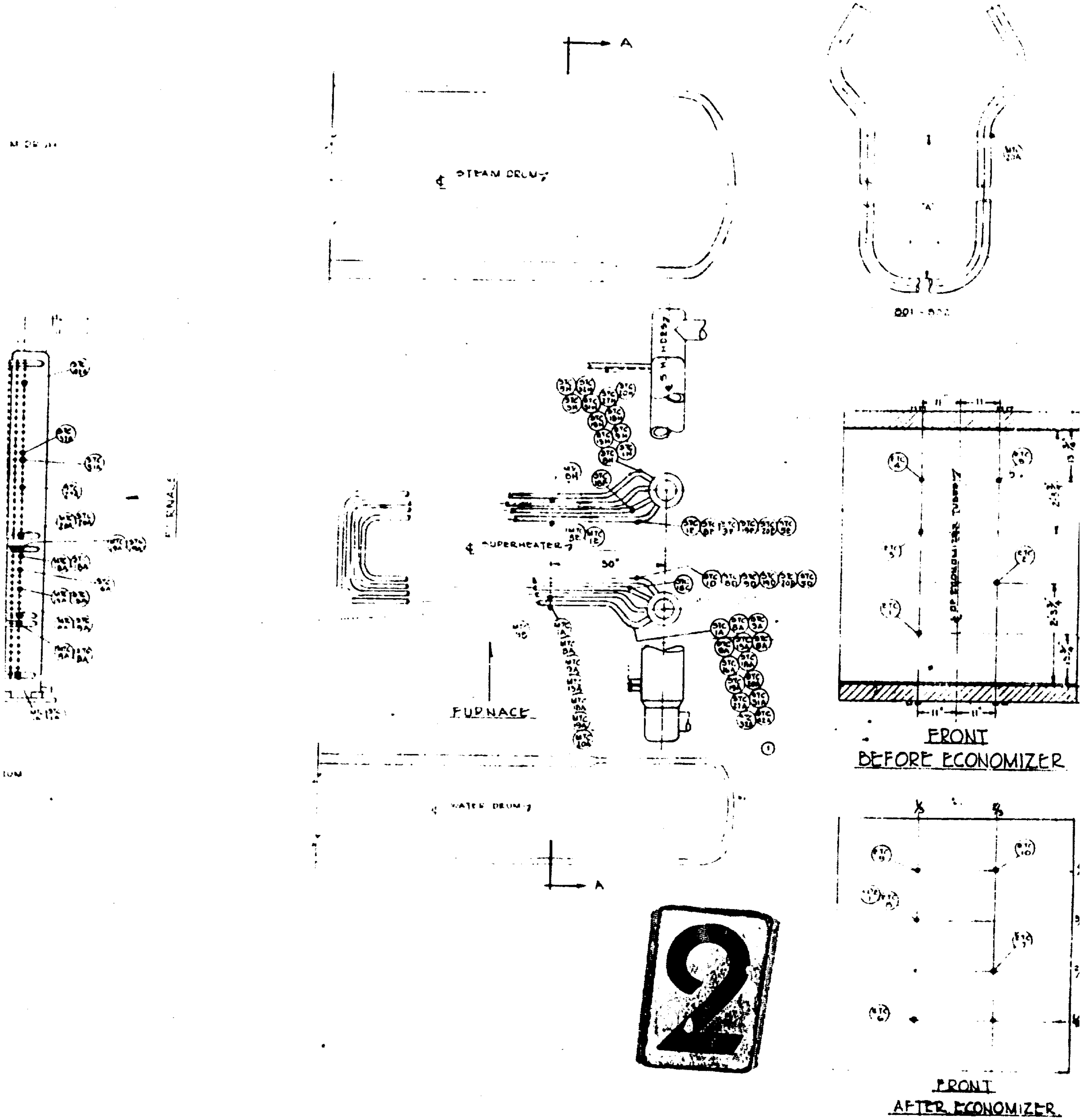


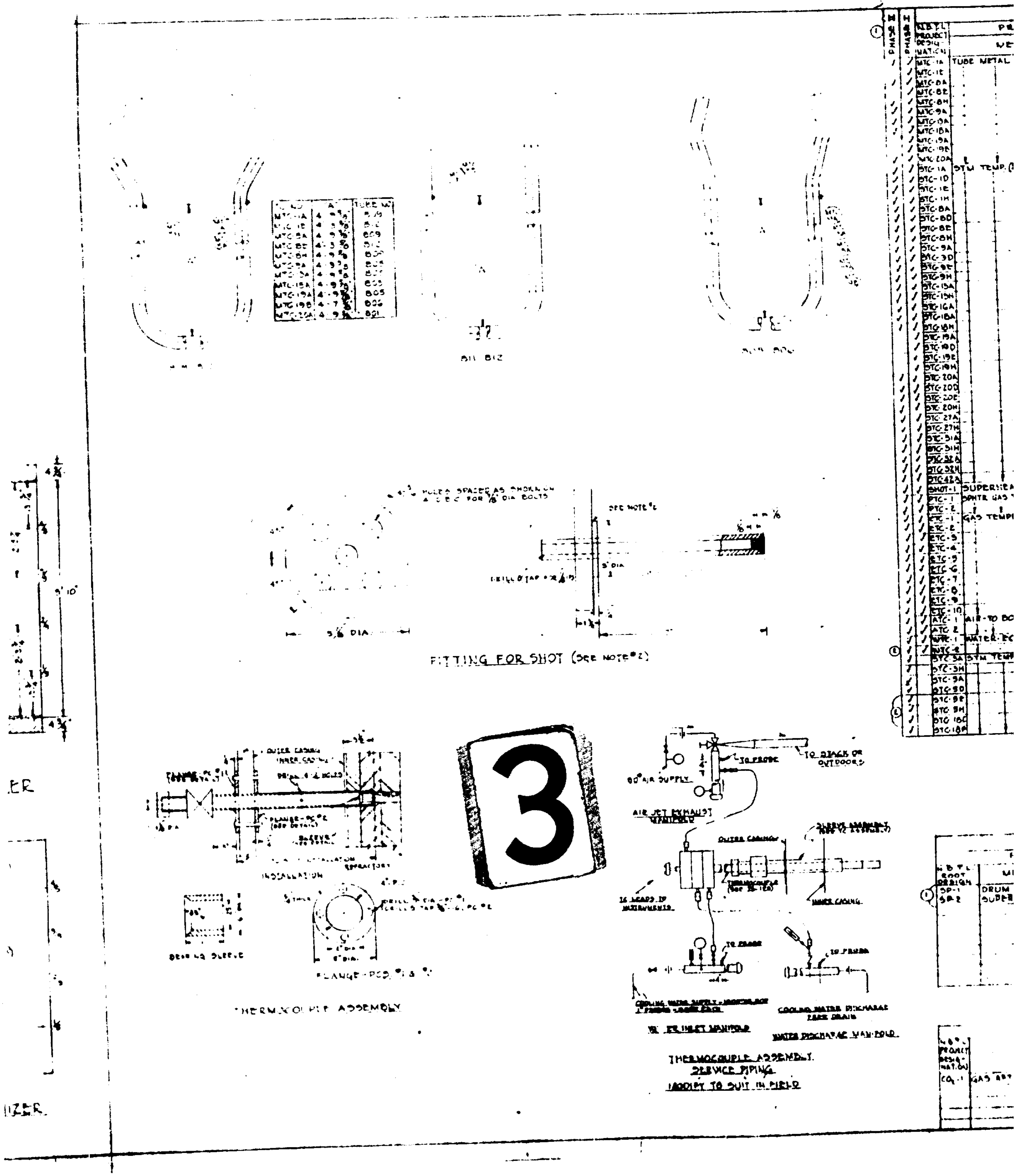
SECTION-AA
PHASE II
(SEE NOTE 4)

1



SECTION-AA
PHASE I
(SEE NOTE 4)


A
STEAM DRUM
SUPERHEATER
30°
FURNACE
WATER DRUM
A
FRONT
BEFORE ECONOMIZER
FRONT
AFTER ECONOMIZER
2


3
FITTING FOR SHOT (SEE NOTE #2)
5/8 DIA
THERMOCOUPLE ASSEMBLY
INSTALLATION
OUTER CASING
INNER CASING
80# AIR SUPPLY
TO PROBE
TO STACK OR OUTDOORS
AIR JET EXHAUST
INNER CASING
WATER DISCHARGE MANIFOLD
THERMOCOUPLE ASSEMBLY
SERVICE PIPING
(MODIFY TO SUIT IN FIELD)
TUBE METAL
STM TEMP.
SUPERHEA
GAS TEMP
AIR TO BO
WATER EC
DRUM
SUPER

THERMOCOUPLES & THERMOWELLS

N.B.T.L. PROJECT DESIGNATION	PRIMARY CONNECTION – MEASUREMENT	TUBE	POINT NO.	RECORDING INSTRUMENT – LOCATION	TYPE	RANGE °F	REMARKS
MTC-1A	TUBE METAL TEMP 1ST ROW TUBE	A	1	SHIPBOARD	SPEEDOMAX	0-2400	MgO SHIELDED
MTC-1E		E	2				
MTC-8A	8TH	A	3				
MTC-8E		E	4				
MTC-8H		H	5				
MTC-9A	9TH	A	6				
MTC-15A	15TH	A	7				
MTC-18A	18TH		8				
MTC-19A	19TH		9				
MTC-9E		E	10				
MTC-20A	20TH	A	11				
STC-1A	STM TEMP (...) 1ST	A	1				
STC-1D		D	2				
STC-1E		E	3				
STC-1H		H	4				
STC-8A	8TH	A	5				
STC-8D		D	6				
STC-8E		E	7				
STC-8H		H	8				
STC-9A	9TH	A	9				
STC-9D		D	10				
STC-9E		E	11				
STC-9H		H	12				
STC-15A	15TH	A	13				
STC-15H		H	14				
STC-16A	16TH	A	15				
STC-18A	18TH	A	16				
STC-18H		H	1				
STC-19A	19TH	A	2				
STC-19D		D	3				
STC-19E		E	4				
STC-19H		H	5				
STC-20A	20TH	A	6				
STC-20D		D	7				
STC-22E		E	8				
STC-20H		H	9				
STC-27A	27TH	A	10				
STC-27H		H	11				
STC-31A	31ST	A	12				
STC-31H		H	13				
STC-32A	32ND	A	14				
STC-32H		H	15				
STC-42A	42ND	A	16			400-1200	
SHOT-1	SUPERHEATER OUTLET					0-3000	
PTC-1	ENTR. GAS TEMP BETWEEN 2ND & 3RD PASS						
PTC-2	3RD & 4TH		12			0-2400	
ETC-1	GAS TEMPERATURE BEFORE ECONOMIZER		13				
ETC-2			14				
ETC-3			15				
ETC-4			16			0-1800	
ETC-5	AFTER						
ETC-6							
ETC-7							
ETC-8							
ETC-9							
ETC-10			13				
ATC-1	AIR TO BOILER - BLOWER DISCHARGE						CONNECTIONS NOT SHOWN - FIELD INSTALLATION
ATC-2							
WTC-1	WATER ECONOMIZER INLET						
WTC-2	OUTLET					0-2400	
STC-5A	STM TEMP (SH) 5TH TUBE	A	4				
STC-5H	5TH	H	9				
STC-9A		A	10				
STC-9D		D	1				
STC-9E		E	4				
STC-9H		H	5				
STC-10C	10TH	C	2				
STC-18A		E					

NOTES:—

1. CONTACT FACE OF FLANGES TO HAVE A PHONOGRAPHIC FIN[ISH] 60 TO 80 SERRATIONS PER INCH, .002" TO .0005 DEEP.
2. SEE 15-112 FOR MATERIAL SPECIFICATIONS
3. THE GAGES USED TO MEASURE PRESSURE AT THE FOLLO[WING] LOCATIONS ARE TO BE CALIBRATED BY SHIPS FORCE P[RIOR] TO AGENDA OPERATION:
   A- DRUM
   B- SUPERHEATER OUTLET
   C- DESUPERHEATER INLET
   D- DESUPERHEATER OUTLET
   E- FUEL OIL SUPPLY
4. PHASE I - SUPERHEATER AS ORIGINALLY INSTALLED
   PHASE II - SUPERHEATER WITH FOLLOWING TUBES REMOV[ED]
   14 INNER TUBE
   15
   16
   17
   18
   19 ALL

4

PRESSURE MEASUREMENTS

N.B.T.L. DESIGN.	PRIMARY CONNECTION – MEASUREMENT	TYPE FITTING	SIZE I.P.S.	REF. DWG.	N.B.T.L. INSTR. DESIGN.	INDICATION OR RECORD – LOCATION	TYPE	RANGE	DIAL SIZE	REMARKS
SP-1	DRUM OUTLET	TEE	3/4"	–	SP-1	DIRECT MOUNTED	TEST	0-4000	6"	
SP-2	SUPERHEATER OUTLET			–	SP-2					

CO₂ MEASUREMENT

N.B.T.L. PROJ. DESIGNATION	PRIMARY CONNECTION – LOCATION	TYPE	SIZE I.P.S.			REF. DWG.	NO.	INDICATION OR RECORD – LOCATION	TYPE	RANGE	REMARKS
O_2	GAS AFTER ECONOMIZER	CONT.	1/4	FLOW	1/2"	15-46		SHIPBOARD NEAR ...	...		

PLATE 5

PHILA. NAVAL SHIPYARD

NAVAL BOILER AND TURBINE LABO[RATORY]

N.B.T.L. PROJECT

INSTRUMENTATION TO DETER[MINE] SUPERHEATER PERFORMANCE

DD-931 CLASS

H-3

THERMOCOUPLES & THERMOMETERS

MEASUREMENT	TUBE	TYPE	SIZE IPS	REF DWG	MATERIAL	REF DWG	POINT NO	LOCATION	TYPE	RANGE °F	REMARKS
[illegible] METAL TEMP 1ST ROW TUBE	1ST, 8TH, 9TH, 13TH, 15TH, 19TH, 20TH	[illegible]	–	15-48[illegible]	M A	15-[illegible]	1–10	[illegible]BOARD	SPEEDOMAX	0-2400	M. C. SHIELDED
[illegible] M TEMP ([illegible])	1ST, 8TH, 9TH, 15TH, 16TH, 18TH, 19TH, 20TH, 27TH, 31ST, 32ND, 42ND	[illegible]	–				1–16				
[illegible]PERHEATER OUTLET		[illegible]			I C		[illegible]			400-[illegible]	
[illegible] HTR. GAS TEMP BETWEEN 2ND & 3RD PASS; 3RD & 4TH		[illegible]			C.R.	15-1[illegible]				0-3000	
[illegible] TEMPERATURE BEFORE ECONOMIZER		[illegible]	1/2	15-6[illegible]	M A	15-65	12–16			0-2400	
AFTER				15-64	I C	15-64				0-1000	
[illegible] TO BOILER - BLOWDOWN DISCHARGE		[illegible]	3/4	15-5[illegible]			13				CONNECTIONS NOT SHOWN - FIELD INSTALLATION
[illegible]TER ECONOMIZER INLET / OUTLET		[illegible]	–	15-8[illegible]			14–16				
[illegible] M TEMP ([illegible]) [illegible] TUBE	5TH, 10TH	[illegible]	–		M A					0-2400	

NOTES:—

1. CONTACT FACE OF FLANGES TO HAVE A PHONOGRAPHIC FINISH [illegible] 60 TO 80 SERRATIONS PER INCH, .002" TO .0005 DEEP.
2. SEE 15-112 FOR MATERIAL SPECIFICATIONS.
3. THE GAGES USED TO MEASURE PRESSURE AT THE FOLLOWING LOCATIONS ARE TO BE CALIBRATED BY SHIPS FORCE PRIOR TO AGENDA OPERATION:
   - A- DRUM
   - B- SUPERHEATER OUTLET
   - C- DESUPERHEATER INLET
   - D- DESUPERHEATER OUTLET
   - E- FUEL OIL SUPPLY
4. PHASE I - SUPERHEATER AS ORIGINALLY INSTALLED
   PHASE II - SUPERHEATER WITH FOLLOWING TUBES REMOVED
   - 14 INNER TUBE
   - 15
   - 16
   - 17
   - 18
   - 19 ALL

5

PRESSURE MEASUREMENTS

MEASUREMENT	TYPE	SIZE IPS	REF DWG	DWG	N.B.T.L. INSTR. DESIG.	LOCATION	TYPE	RANGE	[illegible]
DRUM OUTLET	[illegible]	1/4	–	–	SP-1	DIRECT MOUNTED	[illegible]	[illegible]	[illegible]
SUPERHEATER OUTLET					SP-2				

[illegible] MEASUREMENT

LOCATION	TYPE	SIZE IPS	REF DWG	NO	LOCATION	TYPE	RANGE	REMARKS
[illegible] AFTER ECONOMIZER	CONT.	1/4	[illegible] 15-6[illegible]		[illegible] BOARD MOUNTED	[illegible]		

PLATE 5

PHILA. NAVAL SHIPYARD — NAVAL BASE PHILA. 12, PA.

NAVAL BOILER AND TURBINE LABORATORY

N.B.T.L. PROJECT B-494

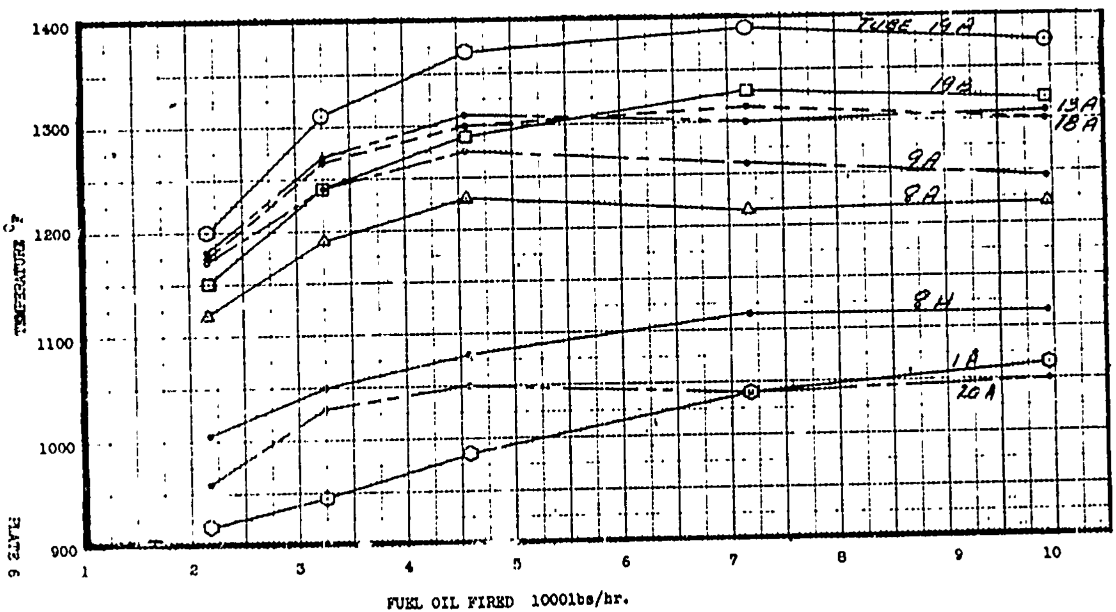
INSTRUMENTATION TO DETERMINE SUPERHEATER PERFORMANCE & 300 BOILER DD-931 CLASS

H-3603 ALT. 2

DD 931 SUPERHEATER STUDIES
USS BARRY (DD 933) BOILER 2B

SUPERHEATER METAL TEMPERATURES

CONDITION A (ORIGINAL SHIPBOARD SUPERHEATER CONFIGURATION)



DD 931 SUPERHEATER STUDIES
USS BARRY (DD 933) BOILER 2B

SUPERHEATER METAL TEMPERATURES (TUBE 19A)

CONDITIONS A & B

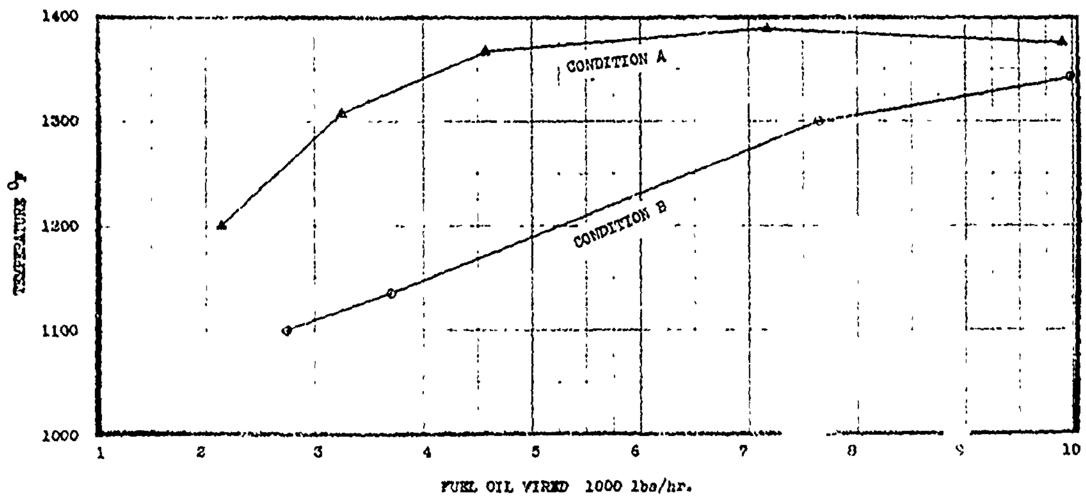
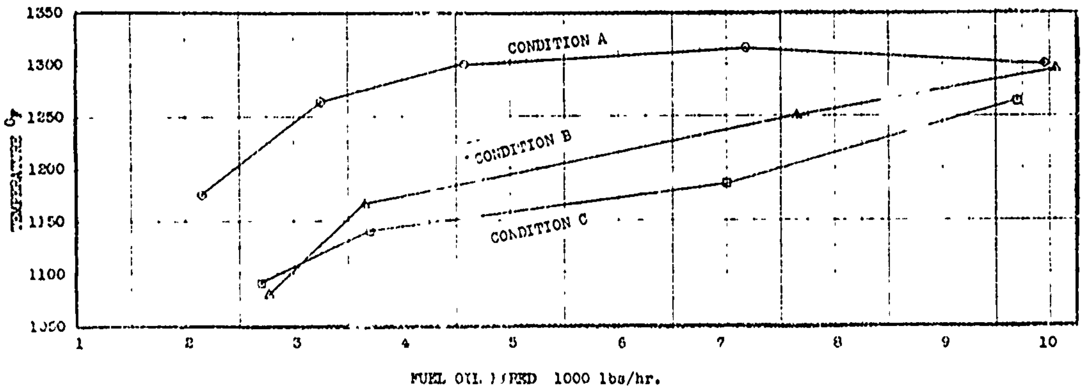


PLATE 7

DD 931 SUPERHEATER STUDIES
USS BARRY (DD 933) BOILER 2B

SUPERHEATER METAL TEMPERATURES (TUBE 18A)

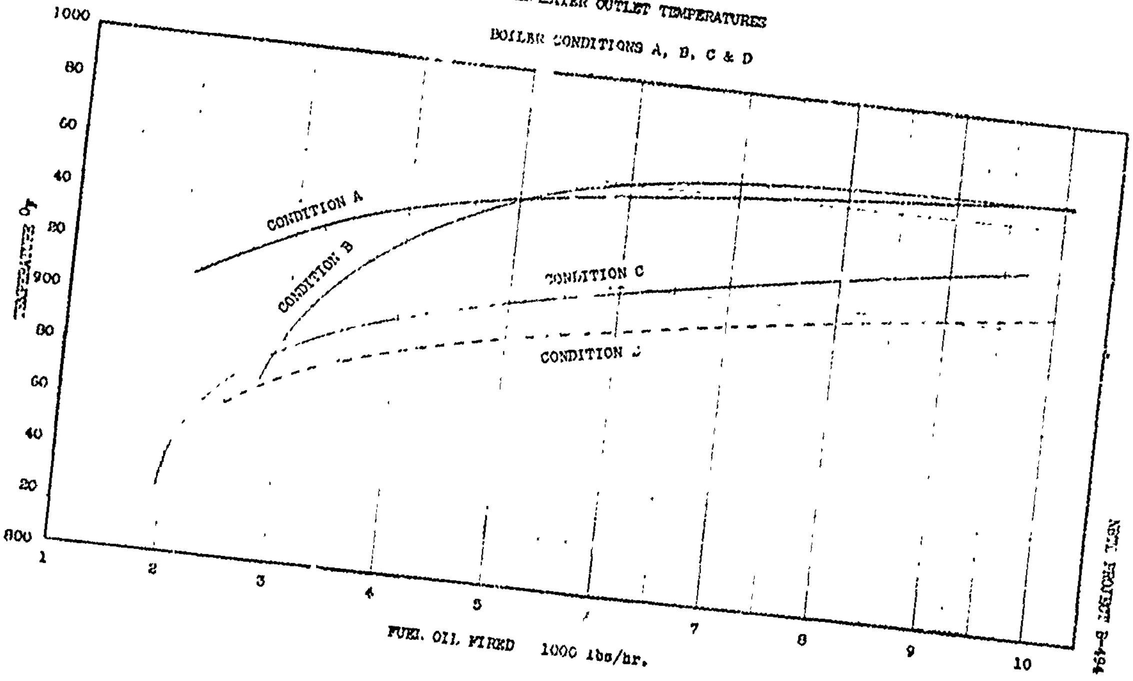
BOILER CONDITIONS A,B and C



DD 931 CLASS SUPERHEATER STUDIES
USS BARRY (DD 933) BOILER 2B

SUPERHEATER OUTLET TEMPERATURES

BOILER CONDITIONS A, B, C & D



DD 931 SUPERHEATER STUDIES
USS BARRY (DD 933) BOILER 23

SUPERHEATER TUBE METAL TEMPERATURES

(OBSERVED FOR BOILER CONDITIONS A,B & C AND CALCULATED FOR CONDITION D)

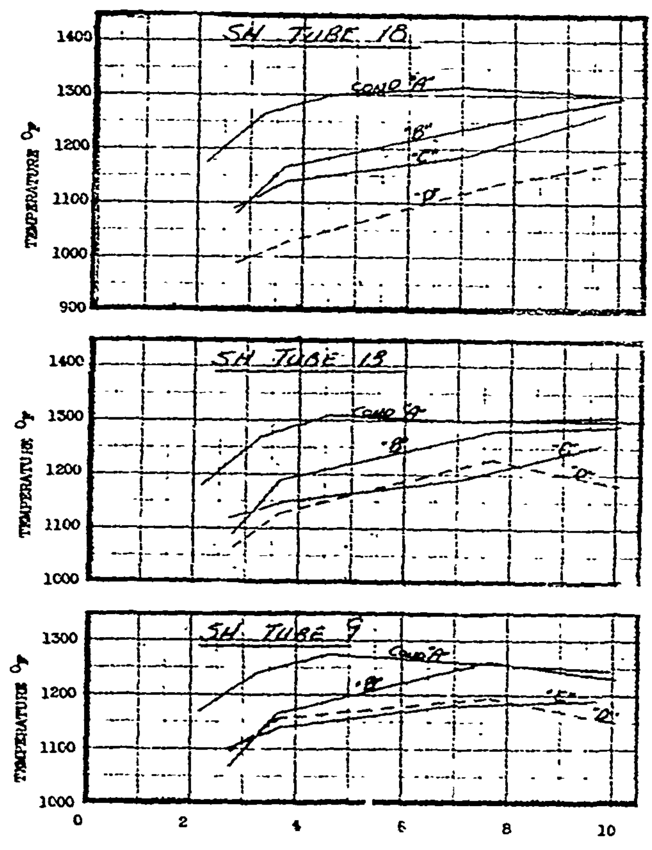


PLATE 10

CC 431 SUPERHEATER ...

PERTINENT DATA

RUN		Condition A 5	Condition A 6	Condition A 9	Condition A 8	Condition B 12	Condition B 16	Condition B 17	Condition B 18	Condition C 21	Condition C 22	Condition C 2[illegible]
TIME		0955 / 1008	1033 / 1056	1300 / 1310	1130 / 1140	0850 / 0913	1018 / 1031	1048 / 1101	1110 / 1125	1003 / 1018	1042 / 1055	[illegible]
% Full Power	%	21	32	69	96	27	35	74	97	21	37	[illegible]
Oil Rate	lb/hr	2170	3259	7173	9960	2167	3445	7601	10,049	2138	3830	[illegible]
Total Steam Rate	lb/hr	31,449	46,250	96,851	134,126	30,859	54,347	103,922	135,197	39,592	56,258	[illegible]
Desup Stm Rate	lb/hr	6007	6568	9879	15,152	6217	6629	10,102	15,677	6327	6922	[illegible]
% CO_2	%	10.8	12.6	13.0	14.2	7.8	9.5	14.4	14.9	9.9	9.5	[illegible]
HHV of Fuel	btu/lb	18,861 →				18,861 →				18,861 →		
Total Sensible Heat	btu/lb	18,870	18,873	18,882	18,869	18,876	18,865	18,864	18,871	18,874	18,865	[illegible]
Efficiency "by heat loss"	%	89.57	89.34	86.89	85.85	86.99	87.21	87.88	86.81	88.71	87.21	[illegible]
Steam Drum Press	PSIG	1210	1225	1210	1250	1190	1250	1155	1240	1226	1236	[illegible]
Superheater Out Press	PSIG	1216	1216	1196	1186	1206	1251	1134	1166	1216	1226	[illegible]
Desup Out Press	PSIG	1185	1195	1145	1125	1195	1165	1110	1145	1175	1160	[illegible]
Windbox Press	in H_2O	6.5	11.2	30.5	39.5	10.0	15.0	27.5	36.0	11.0	13.5	[illegible]
GAS TEMPERATURES IN CAVITY	°F											
2 & 3 Pass (40" from rear wall)	°F	1569	1764	2436	2692	1348	1610	2258	2307	1768	1569	[illegible]
2 & 3 Pass (20" from rear wall)	°F	1339	—	2378	2516	1323	1449	1950	2183	—	—	—
3 & 4 Pass (20" from rear wall)	°F	1655	1181	2313	2423	1493	1791	2392	2461	1564	1565	[illegible]
3 & 4 Pass (25" from rear wall)	°F	1636	—	2234	2555	1456	1191	2234	2465	—	—	—
Gas Temp Before Econ	°F	654	715	883	999	670	700	860	960	651	708	[illegible]
Gas Temp After Econ	°F	317	341	426	485	345	350	405	451	320	350	[illegible]
Econ Inlet Water Temp	°F	261	262	260	255	265	265	266	260	258	260	[illegible]
Econ Outlet Water Temp	°F	395	400	432	445	436	416	418	425	400	420	[illegible]
Superheater Out Temp	°F	910	930	955	970	870	876	945	966	880	895	[illegible]
Superheater Tube Metal Temps												
Tube 20 H	°F	960	1030	1040	1050	1025	945	1040	1070	720	735	[illegible]
19 H	°F	1200	1310	1310	1370	1100	1105	1300	1295	—	—	—
19 S	°F	1150	1240	1330	1320	1160	1030	1240	1260	—	—	—
18 H	°F	1170	1265	1310	1340	1180	1140	1250	1295	1090	1140	[illegible]
13 H	°F	1180	1270	1300	1310	1090	1120	1260	1290	1120	1150	[illegible]
9 H	°F	1170	1240	1240	1255	1070	1100	1260	1230	1100	1140	[illegible]
8 H	°F	1120	1190	1210	1220	1040	1040	1210	1205	1080	1110	[illegible]
8 H	°F	1005	1050	1115	1115	960	980	1095	1100	780	1010	[illegible]
1 H	°F	920	950	1040	1065	885	945	1015	1045	920	942	[illegible]
Superheater Steam Temp												
Tube Leg 20 A	°F	650	655	650	655	640	645	650	660	665	665	[illegible]
20 H	°F	760	775	785	800	720	745	785	790	745	750	[illegible]
19 A	°F	845	870	900	940	785	810	890	915	—	—	—
19 B	°F	—	—	—	—	—	—	—	—	—	—	—
19 H	°F	730	750	755	770	705	725	760	765	—	—	—
18 A	°F	820	845	870	900	770	800	870	890	815	820	[illegible]
18 H	°F	725	745	750	760	705	725	755	760	730	740	[illegible]
13 A	°F	850	875	895	910	805	825	890	900	825	830	[illegible]
13 H	°F	730	750	750	770	700	720	745	760	690	700	[illegible]
9 A	°F	855	875	880	895	800	830	880	885	820	820	[illegible]
9 H	°F	730	750	750	770	700	720	740	750	690	695	[illegible]
8 A	°F	835	860	880	895	780	815	870	885	810	820	[illegible]
8 H	°F	895	915	940	965	830	870	950	960	770	775	[illegible]
1 A	°F	810	835	865	880	765	790	850	860	790	710	[illegible]
1 H	°F	860	895	915	935	815	855	920	930	830	835	[illegible]

1

CD 93: SUPERHEATER ...

PERTINENT ...

NET. PROJECT E-494

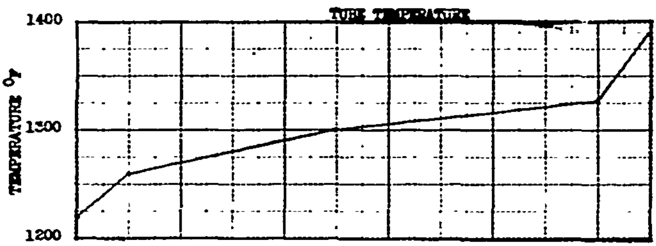
		Condition A				Condition B				Condition C				Condition D Calculated			
		5	6	9	8	12	16	17	18	21	22	24	25				
		0955 1008	1033 1052	1300 1310	1130 1140	0852 0913	1018 1031	1048 1101	1110 1125	1003 1018	1042 1055	1150 1202	1222 1235				
	%	21	32	69	96	27	35	74	97	21	37	68	94	27	35	74	97
	lb/hr	2170	3259	7173	9960	2167	3645	7651	10,069	2138	3850	7010	9100	2167	3645	7651	10,049
	lb/hr	31,449	44,251	96,851	131,156	32,859	54,347	103,902	135,197	39,592	53,658	93,793	130,853	35,859	54,347	103,902	135,197
	lb/hr	6007	6568	9879	13,152	6217	6829	10,702	15,677	6327	6922	9100	14,592	6217	6829	10,702	15,677
	%	10.8	12.4	13.0	14.2	7.0	9.5	14.4	14.9	9.9	9.5	12.5	14.1	7.6	9.5	14.4	14.9
	Btu/lb	18,861 →				18,861 →				18,861 →				18,861 →			
of	Btu/lb	18,870	18,873	18,882	18,869	18,876	18,885	18,864	18,871	18,874	18,885	18,882	18,876	18,876	18,885	18,884	18,871
	%	89.57	89.34	86.89	85.85	85.99	87.21	87.88	86.81	88.71	87.21	86.49	86.33	85.26	86.60	85.94	85.24
	PSIG	1210	1225	1210	1250	1190	1250	1155	1240	1228	1236	1232	1259	1190	1230	1155	1240
	PSIG	1216	1216	1196	1186	1206	1251	1136	1186	1216	1226	1194	1194	1206	1251	1136	1186
	PSIG	1185	1195	1145	1125	1195	1185	1110	1145	1175	1180	1155	1145	1195	1185	1110	1145
	in H_2O	6.5	11.2	30.5	39.5	15.0	15.0	27.5	36.0	11.0	13.5	32.0	35.5	15.0	15.0	27.5	36.0
	°F																
	°F	1569	1764	2456	2692	1358	1610	2258	2367	1768	1509	1959	2134				
	°F	1339	-	2376	2516	1323	1479	1950	2183	-	-	-	-				
	°F	1655	1781	2513	2623	1493	1791	2392	2461	1504	1565	2019	2178				
	°F	1636	-	2234	2555	1456	1791	2234	2465	-	-	-	-				
	°F	654	715	885	999	670	700	860	960	631	708	884	959				
	°F	317	341	426	465	345	350	405	451	320	350	430	455				
	°F	261	252	260	255	265	265	260	260	258	260	258	255				
	°F	395	400	432	445	426	416	418	425	400	420	440	425				
	°F	910	930	955	970	870	896	945	966	880	895	925	942	866	882	913	925
	°F	960	1030	1040	1050	1025	945	1040	1070	720	735	985	1040				
	°F	1200	1310	1310	1370	1100	1105	1300	1345	-	-	-	-				
	°F	1150	1240	1330	1320	1060	1030	1220	1260	-	-	-	-				
	°F	1170	1265	1310	1340	1180	1140	1250	1295	1090	1140	1190	1265	969	1025	1156	1180
	°F	1180	1270	1300	1370	1090	1120	1280	1390	1120	1150	1205	1255	1065	1129	1232	1179
	°F	1110	1240	1280	1255	1070	1100	1280	1230	1100	1140	1190	1190	1097	1155	1194	1151
	°F	1120	1190	1210	1220	1020	1060	1210	1205	1080	1110	1180	1190				
	°F	1005	1050	1115	1115	960	980	1095	1100	780	1010	1080	1075				
	°F	920	950	1080	1065	885	945	1015	1045	920	942	1000	1040				
	°F	650	655	650	655	640	645	650	660	665	665	660	670				
	°F	760	775	785	800	720	745	785	790	745	750	785	805				
	°F	845	870	900	940	785	810	890	915	-	-	-	-				
	°F	-	-	-	-	-	-	-	-	-	-	-	-				
	°F	720	750	755	770	705	725	760	765	-	-	-	-				
	°F	820	845	870	900	770	800	870	890	815	820	850	885	784	804	850	865
	°F	725	745	750	760	705	725	755	760	730	740	750	770				
	°F	850	875	875	910	805	825	890	900	825	830	865	885	845	864	908	915
	°F	730	750	750	770	700	720	745	760	690	700	710	730				
	°F	855	875	880	895	800	830	880	885	820	820	835	870	826	853	816	880
	°F	730	750	750	770	700	720	740	750	690	695	720	735				
	°F	835	860	880	895	780	815	870	885	810	820	850	870				
	°F	895	915	940	965	830	870	950	960	770	775	835	870				
	°F	810	835	865	880	765	790	850	860	790	790	820	850				
	°F	860	895	915	935	815	855	920	930	830	835	870	890				

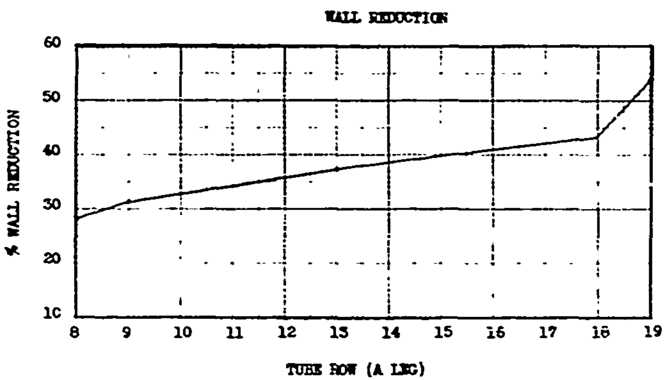
2

DD 951 SUPERHEATER STUDIES
USS BARRY (DD 933) BOILER 2B

SUPERHEATER TUBE TEMPERATURES AND WALL REDUCTION

(TEMPERATURES OBSERVED FOR 25 KNOTS, CONDITION A)





APPENDIX I

AGENDA

AGENDA FOR SUPERHEATER ANALYSIS TESTS
TO BE CONDUCTED ON USS BARRY(DD933)

18 September 1961

Authority:

1. Tests to determine conditions in the superheaters of Babcock & Wilcox DD931 Class boilers that have lead to tube thinning and failure were requested by Bureau of Ships letter DD931 C1/9510; DD945 C1/9510; Ser 651A-947 of 29 June 1961. The approval for superheater tests, to be conducted on USS BARRY (DD933), was given in Commander Destroyer Force, United States Atlantic Fleet dispatch 031966Z of July 1961. By Boston Naval Shipyard Request for Performance of Work WR2-0202 of 7 July 1961 the Boiler and Turbine Laboratory was furnished funds in the amount of $10,000.00 to instrument one boiler on USS BARRY and to provide consultant services for the test. Bureau of Ships letter DD933; Ser 651A-1007 of 17 July 1961 outlined the purpose and procedures for conducting superheater tests in more detail than in the Bureau of Ships letter of 29 June 1961. On 19 June 1961, a conference was held at Naval Shipyard, Boston with representatives of the Shipyard, USS BARRY, Boiler and Turbine Laboratory, and Babcock & Wilcox present. At this conference procedures and responsibilities for test preparation and conducting of tests were discussed. This agenda is a final procedure for the complete test, its preparation, performance, and evaluation.

Purpose of Tests:

2. The primary consideration of these tests is to make an analysis of a superheater in a DD931 Class Babcock & Wilcox steaming boiler to determine (1) conditions under which tube corrosion is taking place, (2) what measures can be taken to extend superheater life, and (3) methods

that can be used to predict superheater tube life. These objectives will be obtained by instrumenting one superheater to primarily determine the following: (1) tube metal temperatures in the second, third, and fourth pass superheater tubes; (2) steam temperatures at various locations in the superheater steam passes; (3) combustion gas temperatures in the superheater cavity; and (4) supplementary information to assist in making a complete analysis of the problem. Data is to be obtained both before and after installation of a gas baffle in a lane between second and third pass superheater tubes on the furnace side of the superheater. It is in the area below this lane wherein serious superheater tube corrosion is being experienced.

Background:

3. Superheater tube failures by bursting have occurred in superheaters of DD931 Class Babcock & Wilcox boilers. The first two of these failures occurred on USS FORREST SHERMAN and were located as follows:

Boiler 1B - 19th tube up - A or outer loop
Boiler 1A - 19th tube up - B or 2nd loop in

These failures occurred immediately prior to 5 May at which time boilers had the following steaming hours:

1A	1B	2A	2B
11892	11819	12102	12187

Approximately 12 May, FORREST SHERMAN had another superheater tube failure as follows:

Boiler 2B - 19th tube up - B or 2nd loop in

4. At approximately the same time as the FORREST SHERMAN failures, JOHN PAUL JONES (DD932) had a superheater tube failure as follows.

Boiler 1B - 19th tube up - B or 2nd loop in

USS MANLEY (DD940) also had a ruptured superheater tube failure in the 19th tube from the bottom in the A or outer loop.

5. All superheater tube failures had the following similarities:

a. Location of all failures was in the 19th row from the bottom on the furnace side leg. This 19th row is the top tube row of the lower furnace side header section and has a 2-1/2" space between it and the bottom tube row of the upper header section. The 19th row is in the third pass; the 20th row in the second pass.

b. All tube failures occurred on the outer loop or in the second loop in.

c. All ruptures occurred on the tube side facing the furnace.

d. All ruptures occurred approximately 30" from the superheater header.

e. All ruptures were thick lipped but varied in size from slits with little bulging to rather large ruptures (4" long x 1-3/4" across the opening) with much bulging.

f. Tube walls of tubes in the area of the ruptures had thinned on the gas side on the side of the tubes facing the furnace. This was especially so in the outer loop tubes and thinned tubes included tubes from at least 13th tube from the bottom to 19th tube from the bottom.

g. All failed tubes were 18 Cr - 8 Ni alloy with nominal wall thickness of 0.156". All tubes in the 3rd and 4th pass are of this material.

6. During examination of boilers 2A and 2B on FORREST SHERMAN on 5 May 1961, it was noted that there was quite a difference in appearance between the superheater tubes of the top two passes and those of the

bottom two. It was noted that the bottom two passes showed signs of corrosion and overheating toward the rear that were not nearly as evident toward the front and that these signs were non-existent in the upper two passes.

7. Observations similar to the above were repeated on boiler 1B of JOHN PAUL JONES on 16 May 1961 and were verified by special inspection of FORREST SHERMAN on 31 May 1961 when it was also determined that the 19th, 18th, 17th, 16th, and 15th tubes from the bottom showed very definite signs of corrosion as compared to the tubes below them.

8. Inspection of the BARRY superheaters from furnace and cavity in early July 1961 showed a similar pattern from the firesides, but not nearly as accentuated as on FORREST SHERMAN and JOHN PAUL JONES. Perhaps the difference was due to the fact that BARRY boilers had fewer steaming hours than the boilers of the other two ships.

9. It has been fairly well established that failure of the superheater tubes may be attributed to wall thinning caused by vanadium ash from the fuel oil attacking the superheater in areas where tubes have had a high metal temperature. Materials Laboratory, Boston Naval Shipyard estimated that a fractured tube from the FORREST SHERMAN had reached a temperature in the vicinity of 1300°F during boiler operation. This was verified by separate Boiler and Turbine Laboratory data wherein it was determined that the failed tube from JOHN PAUL JONES had operated in the region of 1300°F. It is known that high tube metal temperatures, especially above 1150°F to 1200°F are a prime factor to be considered as concerns the amount and extent of corrosion from residual fuel oil

ash. The amount of corrosion which takes place in a particular boiler will also depend upon gas temperatures and gas velocities entering the various sections of the superheater and the amount and condition of the ash carried along with the gases of combustion. It has been considered that perhaps both gas flow and steam flow maldistribution have increased the corrosion rate on the superheaters in boilers of the FORREST SHERMAN type. To somewhat improve gas flow distribution and to provide some initial improvement in the superheaters, a gas baffle for installation in the space between the 2nd and 3rd passes on the superheater furnace side was authorized by Bureau of Ships dispatch 022038Z of 1 June 1961.

10. The superheaters of the DD931 Class Babcock & Wilcox boilers have four passes containing a total of 180 U-type tubes. Each tube row consists of four separate U-loops so arranged that the space between legs of the innermost loop provides sufficient room for a person to enter the superheater cavity. Both inlet and outlet headers are on the generating bank side of the superheater bank with the inlet header being at the top. Two rows of staggered two-inch screen tubes are located between the furnace and the superheater bank. Superheater tubes of the first two passes are 1-1/4" OD by 0.165" thick and are to Military Specification MIL-T-16286B, Class E; tubes of the last two passes are 1-1/4" OD by 0.156" thick and are to the same specification, but are Class C. The working pressure of the superheater is 1250 psig and the steam temperature at the superheater outlet is a minimum of 925°F at cruising and full power not to exceed 970°F at any rate.

General Considerations and Responsibilities

11. Tests are to be conducted on Boiler 2B of the USS BARRY (DD933) in conjunction with Post Repair Trials out of Boston Naval Shipyard in September 1961. It is expected that tests will be conducted during dock trials and during two days at sea; the first day of sea tests will be conducted with the brick gas baffle between the second and third passes removed; and the second day of tests will be conducted with the gas baffle installed and will follow the first sea tests by about four days.

12. The fact that these tests are being conducted or these tests are desired shall in no way interfere with operation and safety of the ship under its Commanding Officer. An engineer (or officer) from the Philadelphia Naval Shipyard (Naval Boiler and Turbine Laboratory) shall be designated to head the personnel under the Bureau of Ships and Boston Naval Shipyard assigned to assist in taking data and observing these tests. All requests for information, suggestions, etc. will be made through the designated head engineer to Engineering Officer or an officer to be designated by the Commanding Officer of the USS BARRY.

13. It is requested that after each day's runs the USS BARRY furnish the Naval Boiler and Turbine Laboratory with copies of the fireroom, engine room operating records and the bell logs, and fuel oil sample. It would be appreciated that during runs announcement of changes in operating conditions be announced prior to actual commands to assist data takers in properly marking records.

14. Boston Naval Shipyard is requested to install the instrumentation furnished by Philadelphia Naval Shipyard (Naval Boiler and Turbine

Laboratory) remove instrumentation after tests, and furnish assistance as may be required during these tests.

15. Philadelphia Naval Shipyard (NBTL) is assigned the responsibility for coordinating conduct of tests, assuring proper calibration and operation of instruments, preparing all data taking forms, collecting data, observing the behavior of the boiler and preparing a report of the results of the test. Data taken shall be such that a reasonable heat balance be made of the boiler so that an estimate can be made of gas temperatures entering the superheater and superheater cavity.

16. In accordance with the request of Bureau of Ship's letter DD933, Ser 651-1007 of 17 July 1961 that the Boiler and Turbine Laboratory inform interested activities of assistance required for the tests, Boston Naval Shipyard was requested during meeting of 17 August 1961 and by telephone conversation of 14 September 1961 to provide the following assistance:

(a) Install economizer thermocouples and stack gas sampling cone.

(b) Manufacture and install MHVT gas temperature probe sleeves. Install all required connecting piping.

(c) Manufacture and install panel boards for Leeds and Northrup recorders, including electrical outlets and wiring. Install the instruments.

(d) Assist NBTL in installation of instrumentation and calibration of instruments as required.

(e) Provide an orsat apparatus and operator during dock and sea trials.

(f) Provide two data takers during dock and sea trials.

Test Instrumentation:

17. An arrangement and detail of instrumentation for the superheater evaluation is shown in NBTL drawing H-3603-0 of 8 August 1961. In summary the following is the instrumentation set-up for the tests:

(a) A total of eleven thermocouples will be installed on the outer skin of the superheater tubes with all hot junctions in the gas path 30" from the centerline of the superheater headers. Starting to count superheater tubes from the bottom, last pass, and labeling tube legs A to H beginning with the furnace side leg, the following tube locations will have thermocouples: 1A, 1E, 8A, 8E, 9A, 13A, 18A, 19A, 19B, and 20A.

(b) A total of 32 thermocouples will be attached to the superheater tubes adjacent to the superheater headers in the header vestibule. These thermocouples will indicate steam temperature in the various circuits. Counting tube rows from the bottom and assigning A to H designations for the tube legs beginning at the furnace side leg, the following locations will be instrumented:

1A, 1D, 1E, 1H, 8A, 8D, 8E, 8H, 9A, 9D, 9E, 9H, 13A, 13H, 16A, 18A, 18H, 19A, 19D, 19E, 19H, 20A, 20D, 20E, 20H, 27A, 27H, 31A, 31H, 32A, 32H, and 42A.

(c) Two multi-shielded high velocity thermocouple probes will be installed in the superheater cavity to obtain gas temperatures. One will be located in the gas path between the third and fourth passes and the other between the second and third passes.

(d) Five thermocouples will be installed in the gas path before and after the economizer.

(e) A pencil type thermocouple will be installed at the superheater outlet to measure final steam temperature.

(f) Pencil type thermocouples will be installed at both forced draft blower discharges to measure combustion air temperature to the boiler.

(g) Economizer water inlet and outlet temperatures will be measured by peened thermocouples.

(h) CO_2 percentage in the stack gas will be measured using a cone primary element and an orsat apparatus for analysis and readout.

(i) Ship's instrumentation will be used to obtain fuel oil supply pressure and the following steam pressures: steam drum, superheater outlet, desuperheater inlet, and desuperheater outlet.

(j) Ship's fuel oil meter will be used to obtain fuel oil rate.

(k) Air pressure at the windbox will be obtained using ship's manometers.

(l) Fuel oil samples will be obtained and analyzed. Samples will be taken as close to the supply burner manifold as possible during the test runs.

Test Evaluation:

18. During dock trials all instrumentation will be checked-out; final calibrations will be made as required including calibration of the high velocity thermocouple probes, and preliminary data will be obtained.

19. Tests conducted during the first and second day of sea trials will be the same except that the first day the brick gas baffle between the second and third superheater pass will not be installed and on the second day this gas baffle will be installed.

20. All test runs will be made with two boilers operating in the ship under split plant conditions.

21. Steady state runs will be made holding the boiler rate constant for a period of 15 minutes or until superheater tube temperature data becomes steady. Normal fuel oil burner combinations and settings used by the ship will be employed for the test runs. The steady state runs will be conducted at the boiler ratings equavelent to the ship conditions shown in the following table and at boiler full power rating:

Ship Condition Knots	Lbs. Oil/Blr/Hr	Final Steam Temp. °F	Air Press. at Wind-box "H_2O
10	-	-	-
15	2150	880	4
20	3600	950	8
25	7090	970	23
Boiler Full Power	10260	945	42

During the steady state runs, at least two rounds of data will be recorded, and more when runs are longer than fifteen minutes. Data will be recorded on data sheets made-up and arranged in advance by the Boiler and Turbine Laboratory.

22. At completion of the 15K and 25K steady state tests, normal shipboard soot blowing operations should be conducted. At least two rounds of data will be recorded during soot blower operations at each rate.

23. At completion of the boiler full power steady state run, ship's speed should be brought to 25K and held there until all superheater-

temperatures steady-out so as to prepare for the maneuvering run. Maneuvering operations should consist of rapidly reducing the ship's speed from 25K to 10K in the normally practiced procedure. After holding a speed of 10K for 10 minutes, increase ship's speed to 25K. This maneuvering may be repeated to verify data obtained. (Note: The 25K condition is the approximate speed where superheater outlet temperature is expected to reach maximum under steady steaming conditions: a lower speed may be selected by Commanding Officer, USS BARRY if so desired for operating convenience.) Data will be recorded during maneuvering operations.

24. During the time that the boiler is being brought on the line superheater tube metal temperatures, interpass steam temperatures, and data usually recorded in the standard fireroom operating record will be taken every 10 minutes after boiler light-off. Similarly, when the boiler is being secured the same data should be obtained at the same interval until steam generation ceases and for approximately 10 minutes after the bleeder team to the auxiliary exhaust valve is closed.

25. During the period that the ship is getting in and out of port, the instruments recording superheater tube metal and steam temperatures will be cut-in to obtain useful data concerning effects of maneuvers. If any unusual conditions occur, procedures under which they happened will be logged and additional data will be obtained. Copies of the engineer's bell book log only will be required for these periods. Data will be recorded as required during these periods.

26. As time permits, additional steady state runs as follows will be conducted:

(a) At boiler rates below full power, operations will be conducted with various burner combinations in use to determine the effect of burner location upon superheater metal and steam temperatures.

(b) At boiler rates to full power, runs will be conducted with various windbox pressures to determine the effect of various amounts of excess air upon superheater metal and steam temperatures.

27. If conditions permit at anytime during the test period and danger of burning-out superheater thermocouples is not involved or is no longer important, superheater temperature data will be obtained during an emergency high speed lighting-off operation.

28. The possibility exists that data from the first day's sea trials may indicate the necessity of removing superheater tubes in the upper part of the third pass to increase steam velocity in that pass. If this becomes necessary arrangements may be made to remove those tubes before the second day's trials.

29. At completion of all testing, the Boiler and Turbine Laboratory representatives with the assistance of Boston Naval Shipyard will remove all instrumentation. Instrumented superheater tubes will not be removed and renewed.

A. LEE
Head Engineer
Boiler and Heat Exchanger
Branch
Code 651 BUSHIPS

W. A. FRITZ, JR.
Head, Steam Generating
Branch
Naval Boiler and Turbine
Laboratory

15 September 1961

APPENDIX II

CALCULATIONAL PROCEDURE

DD931 SUPERHEATER STUDIES

APPENDIX II

Calculational Procedure used in evaluating Heat Transfer Characteristics for boiler Conditions A, B and C and for predictions of Condition D.

SYMBOLS

A	Outside surface area of tube; square feet.
D	Tube diameter; D_i = inside; D_o = outside, feet.
G	Combustion gas flow; pounds per hour
H	Steam enthalpy; ΔH = total steam enthalpy change per tube per unit time or per superheater pass per unit time; BTU per hour.
h_s	Steam enthalpy per pound of steam; Δh = steam enthalpy change per pound of steam; Btu per pound
h_i	Steam film coefficient of heat transfer; Btu/(hr)(ft^2)(°F)
h_o	Gas film coefficient of heat transfer; Btu/(hr)(ft^2)(°F)
Q	Heat transfer rate; Btu per hour
Q/A	Mean heat transfer rate to steam per square foot of tube surface area based on enthalpy rise of steam; Btu/(hr)(ft^2)
R	Combined resistance to heat flow through tube wall and steam film where $R = 1/h_i + 1/U_c$; (hr)(ft^2)(°F)/Btu.
t	Temperature, deg F; t_s = steam temperature; t_{mo} = outside metal surface temperature of tube; t_g = average gas temperature in vicinity of a tube; Δt_s = temperature drop through steam film; Δt_m = temperature drop through tube wall.
U_c	Thermal conductivity through a tube wall; $U_c = K/l'$ where $l' = 1/2\, D_o \ln(D_o/D_i)$; Btu/(hr)(ft^2)(°F).
W_s	Total steam flow through superheater; pounds per hour
w_s	Average steam flow per superheater tube; w'_s is other than average value of steam flow per tube; pounds per hour per tube.

Tube Temperature Evaluation

This method involves the evaluation of film coefficients and heat transfer rates using data collected during boiler operation under Conditions A, B, and C, and extrapolating the trends of these items for application to Condition D. These boiler conditions are shown schematically in Plate 3 of the report. All calculations used the outer loop superheater tubes (plan piece 805 for third pass and 809 for fourth pass).

Initial attempts at evaluation used tube 8AH, figure 1, as the basis for evaluation since this tube had both metal and steam thermocouples at each end. Using these temperatures to obtain a logarithmic mean temperature difference and a steam enthalpy rise in the tube, a combined average heat transfer coefficient was obtained by the relation:

$$R = \frac{lmtd}{Q/A} = \frac{1}{h_i} + \frac{1}{U_c}$$

This value of R was used along with known data from tube 9AH as indicated in figure 2 to calculate the heat transfer rate at location 2:

$$\frac{Q'}{A} = \frac{t_{mo_2} - t_{s_2}}{R}$$

The ratio:

$$X = \frac{Q'/A}{Q/A}$$

is a factor which relates the heat transfer rate at location 2 to mean heat transfer rate obtained by enthalpy. Assuming that steam flow distribution and gas temperature and flow distribution are constant over the third pass, this factor should hold relatively constant for the pass at a particular boiler steam rate. These R and X values

were then used to calculate outside metal temperatures at location 2 for the remaining tubes in the pass as follows:

$$t_{mo} = (Q/A)(X)(R) + t_s$$

where t_{mo}, t_s and Q/A are for the particular tube being evaluated. This method yielded excellent correlation between calculated and observed metal temperatures for tubes 13 and 18 during Condition A full power run 8. Tube 19 calculated temperature was 50°F higher than observed, and this is probably due to the steam flow through tube 19 being much less than the assumed average. The reduced flow through tube 19 was calculated:

$$w'_s = \frac{A}{RX}\left[\frac{t_{mo}-t_s}{\Delta h}\right] \text{observed}$$

For run 8, tube 19, w_s' was evaluated at 89% of the average w_s for the pass.

The identical procedure was employed for evaluation of Condition B, full power run 18, and resulted in fairly good correlation between calculated and observed metal temperatures. Tube 18 resulted in the poorest correlation with the calculated metal temperature being 30°F below observed. The calculated value for tube 19 agreed within 4°F of observed. This was unexpected and is probably due to the fact that tube 19 effective surface area was reduced by addition of a baffle which countered the effects of reduced steam flow in the calculations.

The foregoing results indicated that the inside (steam) film coefficient varies appreciably with boiler Conditions A, B, and C. It was therefore necessary to evaluate the trend of this coefficient in order to predict its value for boiler Condition D. This was accomplished

by evaluating the inside film coefficient as follows:

$$\frac{1}{h_i} = \frac{(t_{m}-t_s)}{Q/A} - \frac{1}{U_c}$$

for selected boiler rates from 20% to 100% full power, and plotting these values against total steam flow as shown in figure 3. These curves are extrapolated to Condition D by taking 14/9 of the numerical difference between the B and C Condition curves. Similarly, the total heat transferred to the steam for each tube is plotted in figure 4 and extrapolated to the D Condition. Constants predicted in this manner were used in conjunction with information from Condition B test runs in order to predict metal temperatures for boiler Condition D, as follows:

<u>Known</u> (from Condition B test runs; same as in Fig. 2)

Ws

t_{s_1} (entering particular tube)

h_{s_1} (at t_{s_1} and 1200 psia)

A

<u>Assumed</u> (boiler Condition D)

14 tubes removed (remaining = 44-14 = 30)

Baffle added between 2 & 3 passes

<u>Procedure</u>

Evaluate ΔH at Ws (Fig. 4)

Evaluate h_i at Ws (Fig. 3)

$w_s = \frac{Ws}{30}$ LB/hour/tube

$Q/A = \frac{\Delta H}{A}$ Btu/hrFt^2

$\Delta h = \frac{\Delta H}{w_s}$ Btu/LB

Steam Enthalpy at location 2.

$h_{s_2} = h_{s_1} + \Delta h$

Find t_{s_2} at h_{s_2} and 1200 psia from steam tables.

Temperature drop through:

Steam film = $\Delta t_{s_2} = \frac{Q/A}{h_i}$

Tube wall = $\Delta t_{m_2} = \frac{Q/A}{U_c}$

Outside tube metal temperature at location 2:

$$t_{mo} = t_{s_2} + \Delta t_{s_2} + \Delta t_{m_2}$$

Comment

The Q/A value used in these calculations is a mean heat transfer rate for the particular tube based on enthalpy rise. The steam film coefficient is based on observed steam and metal temperatures at location 2 and the mean heat transfer rate. This coefficient is therefore valid only when used with the mean heat transfer rate for evaluation of temperature at location 2.

Results

Resultant tube metal temperatures as calculated by the foregoing method are shown in Plate 10 of the report for tubes 9, 13 and 18. These calculations predict an appreciable reduction in temperature from the C to D boiler Condition for tube 18, but practically no change for tubes 9 and 13. This condition may be explained by the fact that steam enthalpy rise per tube (Btu/hr/tube) is not the same for all boiler conditions. That is, for tube 18, the enthalpy rise increases in the order C, B, A; whereas for tubes 9 and 13 the enthalpy rise increases in the order B, A, C. This indicates that Condition C shifted a

greater portion of the work from the top of the third pass to the lower tubes in the third pass. This greater transfer of heat in tubes 9 and 13 probably overcomes the effects of the increased steam film coefficient due to increased flow per tube during boiler Condition C. This effect is naturally carried through to the extrapolation from Condition C to D.

Gas Flow Distribution

Vertical distribution of gas flow through the third pass was evaluated by determining the gas side film coefficient of heat transfer for tubes 9, 13, 18 and 19 during Conditions A, B, and C by the following approximation:

$$h_o = \frac{Q/A}{t_g - t_{mo}}$$

Since this film coefficient is proportional to G^n for a particular configuration, we may write:

$$\frac{G'}{G} = \left[\frac{h_o'}{h_o}\right]^{\frac{1}{n}}$$

This relation may then be used to compare gas flows to a common base. This was done by relating film coefficients of all tubes under consideration to that for tube 9, Condition A. This procedure resulted in a flow pattern as shown in figure 5 for Conditions A, B, and C. The mean gas flow through the pass increased approximately 5% from Condition A to B full power runs, and increased an additional 48% during the Condition C full power run. This is probably due to the fact that the removal of tubes reduced the resistance to gas flow through the pass. A similar evaluation shows the flow through the third pass will increase

an additional 32% for Condition D. Gas flow through the third pass for Condition D is therefore 85% greater than for Condition A at the full power rate. A similar procedure used the variation in gas side film coefficient to evaluate the horizontal distribution of gas flow for the Condition B full power run. Results indicated that the gas flow through the third pass, at the rear of the furnace was approximately 65% greater than the mean flow through the third pass.

DD 931 SUPERHEATER STUDIES
USS BARRY (DD 933) BOILER 2B

INSTRUMENTATION: TUBE ROWS 8 & 9

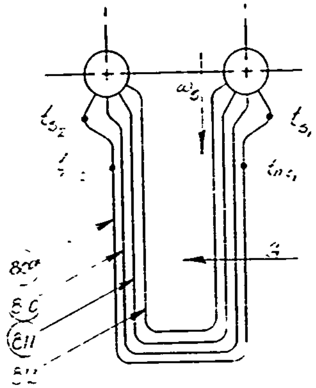


FIG 1

TUBE 8 AH
INSTRUMENT LOCATIONS

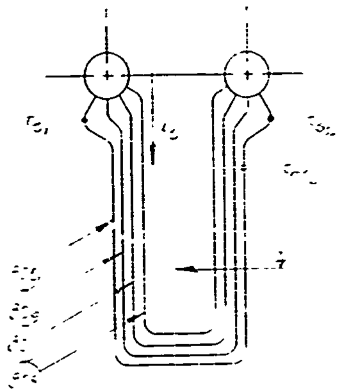


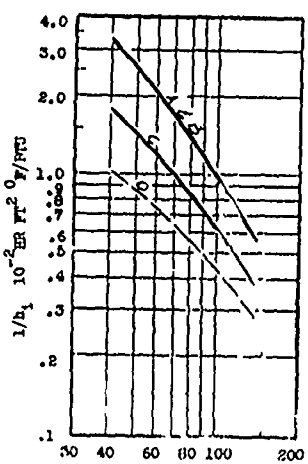
FIG 2

TUBE 9 AH
INSTRUMENT LOCATIONS

DD 931 SUPERHEATER STUDIES
USS BARRY (DD 933) BOILER 2B

STEAM FILM COEFFICIENT OF HEAT TRANSFER
BOILER CONDITIONS A, B, C & D

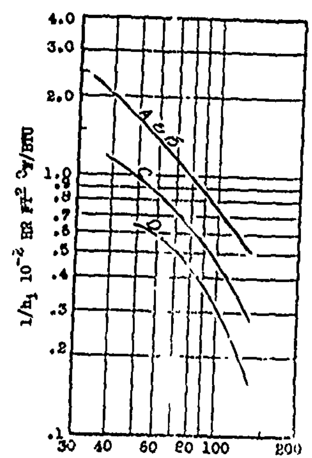
TUBE 18 AH



TOTAL STEAM RATE 1000 lb/hr

FIG 3 (a)

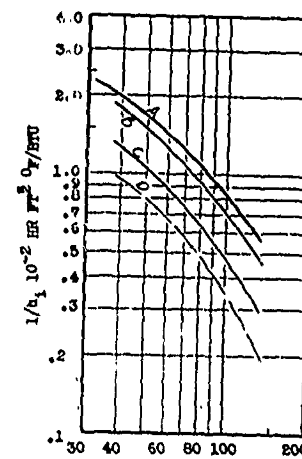
TUBE 13 AH



TOTAL STEAM RATE 1000lb/hr

FIG 3 (b)

TUBE 9 AH



TOTAL STEAM RATE 1000 lb/hr

FIG 3 (c)

DD 931 SUPERHEATER STUDIES
USS BARRY (DD 933) BOILER 2B

STEAM ENTHALPY RISE PER TUBE
BOILER CONDITIONS A, B, C & D

FIG 4(a) TUBE 18 AH

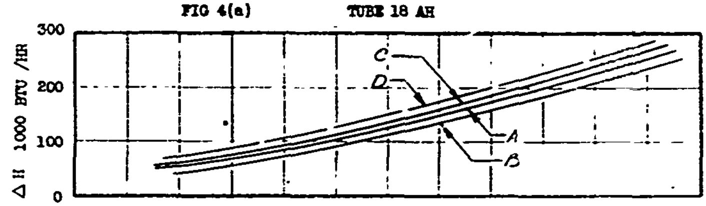


FIG 4(b) TUBE 13 AH

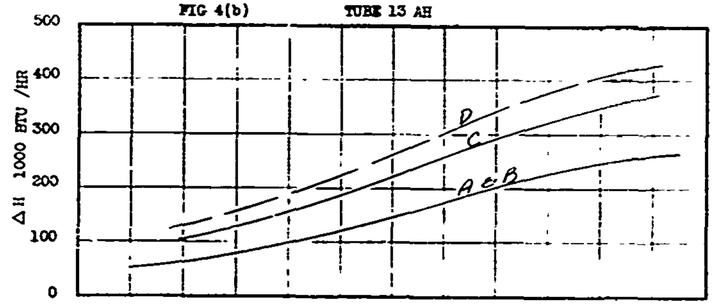
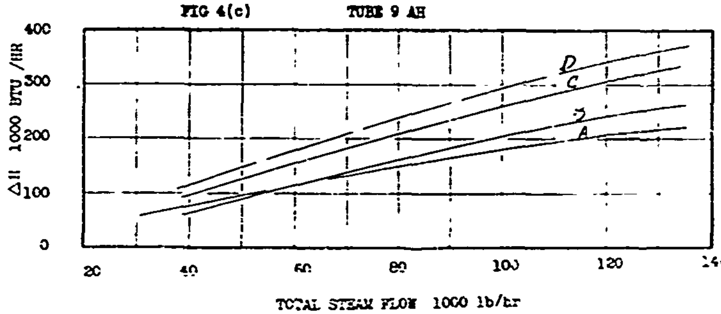


FIG 4(c) TUBE 9 AH



DD 931 SUPERHEATER STUDIES
USS BARRY (DD 933) BOILER 2B

GAS FLOW DISTRIBUTION THROUGH THIRD PASS

BOILER CONDITIONS A, B, C & D

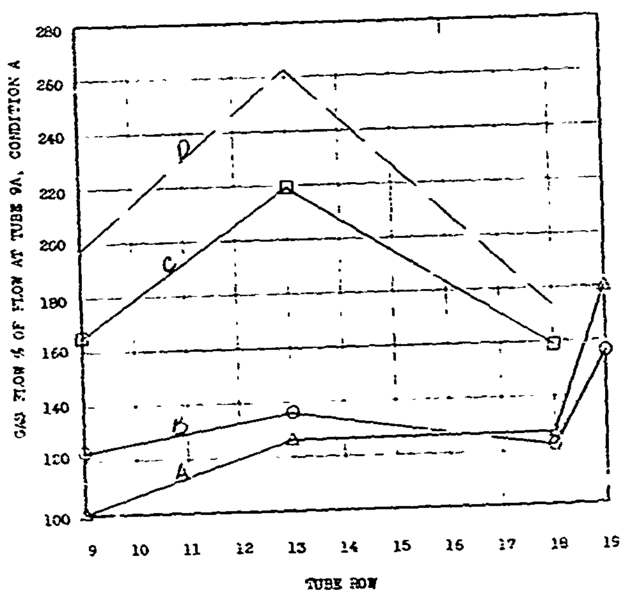


FIG 5

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Project No. B-494
SUPERHEATER EVALUATION STUDIES FOR DD931/DD945 CLASS BABCOCK & WILCOX BOILERS, EVALUATION REPORT, by
W. A. Fritz, Jr.
T. P. Tursi, Jr.
May 1962

16 p., 12 encl.,
2 append.
UNCLASSIFIED

Three ships of the DD931 Class experienced tube failures in the superheater third pass. All failures occurred in the same tube row and all
(over)

1. Heat Transfer Studies
Fuel Ash Corrosion
I. Fritz, W.A., Jr.
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